SETBACKS FROM SLOPE CRESTS FOR STRUCTURES

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[redacted]

SETBACKS FROM SLOPE CRESTS FOR STRUCTURES

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Prepared by:

D. M. CRUDEN AND J. S. DE LUGT
University of Alberta

The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

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Innovative Housing Grants Program
Alberta Municipal Affairs
Housing Division
Research and Technical Support
16th Floor, CityCentre
10155 - 102 Street
Edmonton, Alberta
T5J 4L4

Telephone: (403) 427-8150

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EXECUTIVE SUMMARY

While many of the most desirable sites for residential developments are along the crests of river valleys, these sites are subject to slope movements which can damage or destroy structures or services to them. We need to setback structures to ensure their long term safety. However, no standard design procedure exists for these setbacks.

The objectives of the project are to validate the Cruden, Tedder, and Thomson (1989) model for estimating setbacks for structures from the crest of slopes, to assess the model's impact on developed land in the immediate vicinity of the slope failure, and to review the attributes and effects of the model with a view to its further refinement and broader application. The Cruden, Tedder, and Thomson (1989) model for estimating setbacks for structures is based on the ultimate angle of the slope and the net erosion from the toe of the slope. The ultimate angle is estimated from abandoned slopes in the vicinity. To test this method, the model was applied to ten cases in which landslides in Alberta have resulted in damage to structures.

The selected landslides have damaged or destroyed 30 houses, 2 stables, 1 school, 1 garage, and 2 power poles. In all ten cases, the model estimated setbacks that would have avoided damage to any structure had development followed the recommended setbacks.

The model can be used as a simple and effective method for estimating setbacks. A setback line, drawn the required distance back from the valley crest, indicates the limit up to which development can safely occur without remedial works. Development within the setback will normally require particularily detailed site investigations and stabilization of the slope. The setback may be used as the basis of a municipal bylaw.

SETBACKS FROM SLOPE CRESTS FOR STRUCTURES

1.0 INTRODUCTION

"Tis distance lends enchantment to the view"

Thomas Campbell, 1799
Pleasure of Hope, Part I,7

Many of the most desirable sites for residential developments are at the crests of river valley slopes. It is unfortunate that these sites are subject to slope movements which can damage or destroy structures or services to them. Loss of houses, structures (eg. schools), and building sites have occurred in most of Alberta's riverside cities. Economic and aesthetic considerations have brought housing developments close to the top of the bank.

History indicates the need for establishing setbacks to insure the long term safety of structures from slope movements. However, no standard design procedure exists for the specification of these setbacks. This study tests the reliability of the Cruden, Tedder, and Thomson (1989) model for the specification of setbacks. A case study approach was used to examine situations where actual structural failures due to slope movements have occurred with a view to validation of the model and its further refinement.

1.1 Objectives

The specific project objectives are:

1) to validate the Cruden, Tedder, and Thomson (1989) model for estimating setbacks for structures from the crest of slopes by applying it to cases involving slope movement resulting in property damage;

2) to assess the model's impact on developed land within the immediate vicinity of slope failures examined;

3) to review the attributes and effects of the model with a view to its further refinement and broader application.

The focus of the research was on validating the Cruden, Tedder, and Thomson (1989) model with a view to its application on a larger scale and to its further refinement.

1.2 Organization of the Report

The final document is a compilation of three separate phases. The three phases are as follows:

Phase I:	Review of Current Practice and Identification of Cases
Phase II:	Analysis and Evaluation
Phase III:	Refinement, Presentation and Report.

Phase I reviewed the nature and extent of the problem and the current practice for delineating setbacks for structures. It identified ten cases involving damage to structures and the criteria used in their selection.

Phase II of the report determined topographical details about each case history, the rate of river erosion, the extent of change, the land use in the vicinity, and ultimate slope angles of stable slopes in the vicinity. The Cruden, Tedder, and Thomson (1989) model was applied to determine setbacks for each case. The results from the application of this model was then compared with the extent of change resulting from the slope movement. The land use effect of setbacks generated by the model in the immediate vicinity of slope failures was examined. To conclude this phase, the effects and attributes of the model were reviewed and evaluated. Finally, the prospects for and the utility of

its further refinement and broader application were discussed.

The third and final phase of the report assessed the refinements proposed in the previous phase and examined the revised model to assess reliability. A seminar presentation on the results was also developed in this phase.

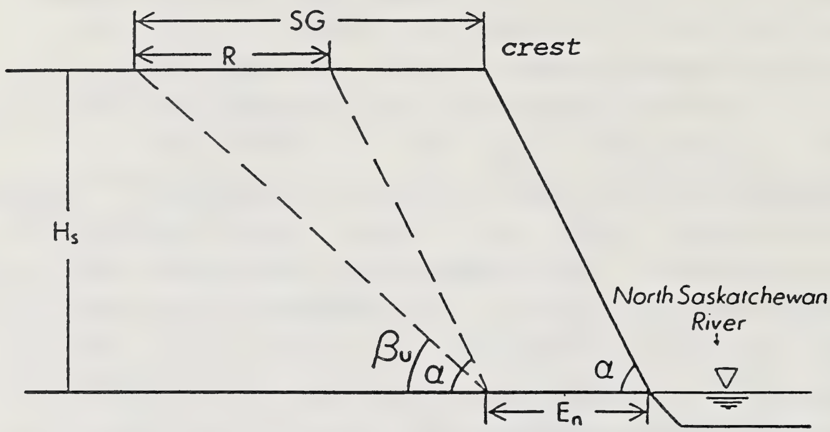
1.3 Methodology

A case history approach was used. Ten cases of loss of housing or other structures were collected from municipal engineers, regional and local planners, and consulting engineers. Documentation of the case histories was from site visits, topographical maps, and air photographs.

Interpretation and evaluation of the case histories was based on the Cruden, Tedder, and Thomson (1989) criteria for establishing setbacks. The guidelines of this model are shown schematically in Figure 1. Contemporary maps and air photographs were used to determine the slope height, H_s, the inclination of the oversteepened slope, α, and the position of the structure with respect to the crest of the slope. More recent maps and photos which show positions of the crest of the valley slope can be used to determine average values of net river erosion (E_n). For this report however, a representative value for net lateral river erosion was determined from available literature.

Ultimate slope angles, β_u, are the angles of mature, abandoned slopes with the same geology and groundwater conditions as the oversteepened slope. Abandoned slopes are those not being eroded by a river at present. Mature, abandoned slopes have not been eroded by a river for hundreds of years or more. These abandoned slopes can be identified through air photo interpretation or from field reconnaissance. Slope angles may be read from maps or measured on site.

Figure 1: Determination of potential regression and setback for an active slope (Cruden et al., 1989).



H_s - height of the slope

β_u - ultimate angle of stability

α - inclination of the oversteepened slope

R - potential long term regression

$= H_s/\tan\beta_u - H_s/\tan\alpha$

En - net lateral river erosion

SG - setback guideline

$= R + E_n$

All the quantities necessary to determine the setback, SG, at a site were found by examination of existing maps and air photos or by unobtrusive site exploration. It is expected that the siting of structures which have been damaged or destroyed in slope movements would violate the setback guidelines. Any structures which have been destroyed although located in accordance with the guidelines were subject to a detailed study to determine what, if any, factors account for their anomalous behaviour.

2.0 CURRENT PRACTICE FOR DELINEATING SETBACKS

In the past, setbacks have been established by theoretical and empirical methods. Townsend and Thomson (1980) suggested setbacks using computer-aided stability analyses based on observation from field mapping, borehole logs and available laboratory test data. The setback was defined as the distance from the valley crest to where a rupture surface with a theoretical Factor of Safety of at least 1.3 intersected the upland. An additional 4 m allows for changes to the slope under development, and also provides access if necessary. This theoretical method for deriving setbacks is suited to specific sites. However, the cost of field mapping, drilling boreholes, laboratory testing and computer analyses is prohibitively high for the application of this method to long stretches of a river valley.

Mollard (1981) established an empirical method for determining setbacks using estimates of the valley crest regression that resulted from slope movements. The scarp of any future slope movement was assumed to develop a distance back from the valley crest similar to that of previous slope movements. The regression measured in slope movements with a particular stratigraphy and groundwater condition was doubled to establish the setback which was presented as a multiple of valley depth. Mackay and Thomson (1980) used

this method for setbacks along the South Saskatchewan River and tributary creek valleys through Medicine Hat, as did Ruban and Thomson (1983) for the valley slopes along the Oldman River and tributary coulees through Lethbridge. This method was suited to long reaches of river valley as it involved only airphoto measurements and field mapping to establish the stratigraphy and groundwater conditions. However, the setbacks lacked a rational technical basis and could be contested by landowners and developers (Cruden et al., 1989). This method is also restricted to valleys where slope movements have occurred within the period covered by available air photos.

Hutchinson (1973) studied the retreat of slopes in London Clay and detailed the progressive slope decrease to an ultimate angle. Early, deep-seated movements are followed by shallow slides. Colluvium accumulates at the toe to form the lower part of the long term slope. He showed that the cliffs in London Clay degraded from an initial slope of up to 30 degrees to an ultimate slope of 8 degrees approximately 1000 years after abandonment. Identification of mature abandoned slopes in the vicinity of the slope is essential to the proposed method for delineating setbacks.

2.1 Recent Setback Studies

Several slope stability studies around the province have led to setback recommendations. Instability of slopes in residential developments can result from increased water infiltration which increases water pressures within the slopes and also reduces the strength of the slope materials. Furthermore, fill placed along the crest of the slope is often unstable. R.M. Hardy and Associates Ltd. (1974) recommended certain setbacks so that increased infiltration would have a minimal effect on the groundwater conditions in slopes. They suggested that setbacks be based on the height

of the slope. The minimum setback for all slopes with toe protection, and higher than 6 m (20 feet) should be 18 m (60 feet) for all buildings, fill, permanent watering systems, and water and sewer lines. For water reservoirs (swimming pools, ponds, septic tanks, etc.) the recommended minimum setback was 30.5 m (100 feet). For those slopes without erosion protection, setbacks for buildings and fill should be increased by at least 30.5 m (100 feet) to minimize the possibility of damage to private property from creek erosion.

In a study of slope stability along the South Saskatchewan River and its tributaries in the vicinity of Medicine Hat, Mackay and Thomson (1980) explained that because of the complexity of the soil deposits in the area, the groundwater regime, and the anthropogenic influence, establishing a standard setback was difficult. They concluded that any development near the crest of a slope should be accompanied by a report from a competent geotechnical engineer or engineering geologist on the short and long term stability of the slopes that are near the proposed development.

In a similar study of the Oldman River and its tributaries in the vicinity of Lethbridge (Ruban and Thomson, 1983) it was again considered difficult to establish a general setback for the prairie upland, so a conservative approach was taken. For preliminary purposes, it was recommended that a setback distance equal to the depth of the valley be used for any proposed developments adjacent to the Oldman River valley. It was also recommended that a perimeter road be used to separate the coulees (or tributary valleys) from any future residential or commercial development. Setbacks should be based on decisions made by a qualified geotechnical engineer, and should take into consideration loading and unloading of the slope, and possible changes to the groundwater regime.

Based on the results of a slope stability study for a section of the North Saskatchewan River, and on the ultimate angle of stability theory, Tedder (1986) suggested that setbacks for active slopes in the study area should be 0.7 to 3.2 times the valley depth.

This setback for active slopes can be compared to previous studies in other urban areas which apply a standard setback based on the amount of valley crest regression measured from active slope movements. In these cases the usual setbacks are 1 to 2 times the depth of the valley (MacKay and Thomson, 1980; Ruban and Thomson, 1983). One disadvantage of the valley crest regression method is that regression measurements from records and airphotos cover a period less than 100 years. In contrast, the ultimate angle of stability concept incorporates the degradation of abandoned valley slopes over several thousand years to provide a guideline for the potential regression of active slopes.

Because abandoned slopes are at their ultimate angle of stability and are no longer affected by lateral river erosion, they are not expected to regress significantly by natural processes within the lifespan of most structures. However, as urban developments often affect groundwater conditions, a minimum setback should be the maximum expected crest regression from slope movements. Tedder (1986) found that in his study area the maximum regression was 15 m over a 60 year period. An additional 5 m would provide access should remedial work be necessary. The recommended minimum setback of 20 m was therefore applied to abandoned valley slopes in the study area, and is 0.5 to 1.5 times the slope height. Tedder (1986) suggests that the guidelines are intended only for preliminary land use decisions and that they should be reassessed within 50 years to incorporate changes in the existing slope conditions.

2.2 Current Legislation

Legislation on setbacks in Alberta exists at both the provincial and municipal level. The Department of the Environment is the legislative and administrative authority for the province. The administrative authority for the City of Edmonton is the Municipal Planning Commission and the legislation is implemented by Municipal Bylaws.

Mostly for aesthetic reasons, development along river valleys usually involves the land adjacent to the valley crest. The crest of the valley is generally defined as the point on the uppermost section of the valley wall where the maximum rate of change in slope occurs. Local bylaws have been established to govern how close to the valley crest developments may take place. These bylaws generally recognize the need to prevent destructive activities such as the placement of fill, the removal of vegetation, or the redirection of water to or into the slope.

Legislation and regulation affecting land development near valley crests is a result of the interaction of the historical and political development of the province and municipalities, the value of land, the pressure to develop available land, and the response of the public and government to the effects of landslides. The bylaws for Edmonton have evidently been affected by the results of law suits brought against the City in cases of alleged damage due to landslides (Harris, 1980).

2.2.1 Edmonton

Urban Edmonton is essentially a century old. For the first 75 years there was no restriction on building near the crest of the valley, or along the river (Townsend and Thomson, 1980). Neither did smaller satellite villages in the vicinity have a policy regulating development near the

crest of the valley, nor were roads generally located at the top of the bank.

The Municipal Planning Commission in Edmonton established a clear policy for development of land adjacent to valley crests. City of Edmonton Bylaw 7188 governs the actions of the subdivision approving authority (the Municipal Planning Commission) in dealing with the subdivision of land abutting the North Saskatchewan River Valley Area Redevelopment Plan Boundary. The Top-of-the-Bank Public Roadway Policy, an attachment to Bylaw 7188, was adopted in 1976 to ensure the preservation of a boundary system in the vicinity of the river banks for the maintenance of areas suitable for public parks, and for areas which need some form of environmental control, especially where slope movements may threaten public or private property.

Geotechnical studies and planning concerns were both incorporated in the Top-of-the-Bank Road Policy. In this policy, the **Top-of-Bank Line** (the valley crest) is defined as the upper valley break line or the line defining the uppermost or most obvious topographic discontinuity in slope distinguishing between the upper plateau and valley wall. The **Top-of-Bank Setback Line** is a surveyed line, established by agreement between a developer and City representatives, defining a setback on the upper plateau a minimum average width of 7.5 m (25 feet) from the Top-of-Bank Line and providing for public access and preservation of vegetation along the Top-of-Bank. The **Development Line** is established by a geotechnical consulting firm at the developer's expense, defining the closest point to the Top-of-Bank Line where development of a particular kind may safely occur. This line is only used in limited circumstances where development is permitted adjacent to the Top-of-Bank or where slope stability is such that the Building Development Line is closer to the topographic Top-of-Bank, than is the Top-of-Bank Setback Line.

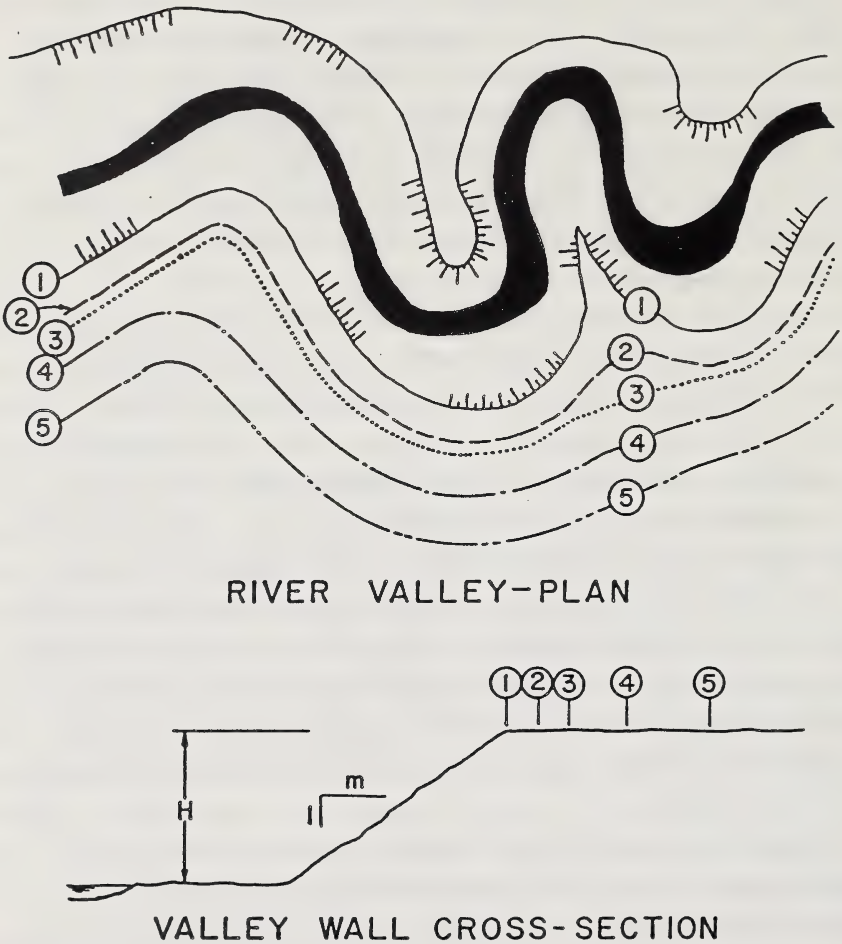
In the Top-of-the-Bank Policy, the Top-of-Bank Setback Line depends on the type of proposed development (roadways, buildings or fill, and swimming pools or water reservoirs) (Figure 2). There is however, a minimum setback of 7.5 metres. Where a top of the bank roadway or lane is to be constructed, the setback is 7.5 metres, unless the results of a geotechnical study indicate a further setback. There are no criteria that indicate when a geotechnical study is necessary. In those cases in which a roadway or lane is not required, there will be a 7.5 metre setback for public access between the geographic top of the bank and any abutting development site.

The present municipal policy indicates that detailed geotechnical engineering studies are only required when no roads along the top of the bank are proposed and when housing and other developments are near the top of the bank. However, Townsend and Thomson (1980) suggested that, in practice, a geotechnical study along the full length of the top of bank within the subdivision is required whether a road will be used or not. This is because developers prefer to finalize the subdivision plan (including street patterns) after the slope study, and because later detailed, municipal engineering studies often indicate the need for specific services, such as storm water outfalls, to be installed down or close to the bank.

To accomodate Edmonton's policy, Townsend and Thomson (1980) outlined an investigative procedure to assess the stability of the slope and to establish setbacks using theoretical analysis. The geotechnical study includes an examination of the local geology, determination of the anticipated geologic stratigraphy, the bedrock elevation, and piezometric conditions. A complete stability analysis also requires the determination of the effective stress and strength parameters of the strata.

The geomorpholgy of the area is also examined, usually through the earliest set of aerial photographs available,

Figure 2: Schematic representation of the Top-of-Bank Policy for the City of Edmonton (Harris,1980).



LEGEND:

1. Top of bank - by survey
2. Buffer, roadway limit - by regulation
3. Development line - by report
4. Building line - by report
5. Water reservoir, sprinkler system and swimming pool limit - by report

and through field inspection. This identifies how the slope was formed, if there have been any earlier slope failures, or if there are any seepage areas. This preliminary reconnaissance may indicate the probability of a slope failure in the future, how it might fail, and the form it might take.

Once data has been collected, a standard slope stability analysis is carried out within conservative guidelines (Townsend and Thomson, 1980). A 'geotechnical line' (Development Line) is then established 4 m back from the crest of the possible failure scarp. This Development Line is established irrespective of any planning or regulatory framework. As the Development Line is often closer to the top of the bank than Top-of-Bank Setback Line the developer may wish to challenge the City.

To summarize, the City of Edmonton policy regarding development along the crests of river valleys has evolved as a result of the desire to ensure public access combined with the need for some environmental protection against the adverse effects of urbanization. There remains however, the conflict between private and public development. The private developer attempts to maximize his opportunities while being required to minimize the potential for future public difficulty (Townsend and Thomson, 1980). If the developer's plans fall within the guidelines of the Top-of-the-Bank Road Policy, then no conflict ensues. However, if the developer wishes to develop land that is closer to the Top-of-Bank Line than the minimum setback requirement established by the City, then the developer retains the services of a geotechnical engineer to establish a Development Line. If this line is in fact closer to the top of the bank than the Top-of-Bank Setback line, then the developer challenges the City.

If the plannned development falls within the Top-of-the-Bank Road Policy guidelines, a geotechnical study is not necessary. If however, as Townsend and Thomson (1980)

suggested, the developer wishes to maximize his opportunities, then a geotechnical study is necessary. In this case, a developer would automatically have a geotechnical study done for the land adjacent to a valley wall. If the Development Line is not in conflict with the guidelines established by the City, then the developer can proceed with the development. Otherwise, the City is challenged by the developer, and an agreement is reached between the two. The City will ensure that the development will not hinder public access to the valley system or adversely affect the stability of the slope.

2.2.2 Calgary

Urbanization has also affected slope stability in the City of Calgary. Major slope stability problems developed in the late 1940's and 1950's. It is possible, in some cases, that the instability was a direct result of the uncontrolled development of areas adjacent to valley walls (Stepanek and Rodier, 1980). Control measures and administrative procedures were introduced in the 1960's. Initially, the use of these measures was dependent entirely upon the discretion of the developer and City officers granting the development permit. The control measure most frequently implemented in the 1960's and early 1970's was the establishment of a safe development setback from the crest of an unstable or potentially unstable slope (Stepanek and Rodier, 1980). This development setback was defined by the geotechnical engineer and was based on an analytical approach. Since 1978 the City of Calgary has instituted a policy requiring a geotechnical evaluation of slope stability for those areas in which the proposed development is adjacent to sloping terrain, encroaches on a slope or involves the undercutting of existing terrain. According to this policy, slope stability reports are required whenever any slope within the property is 8.5° (15 percent) or

greater or when the development is to be located within a zone where the slope between the toe and crest is greater than 19° (1 in 3). Areas with a Factor of Safety (F_S) against failure equal or greater than 1.5 may be considered for development. If the F_S is less than 1.5, the slope may be modified using remedial measures, which are approved by the City Engineer, to increase the F_S to a minimum of 1.5. The Calgary policy clearly outlines the minimum standards to be used in slope stability studies.

The intent of the policy is to prevent loss of life, to protect property, and to minimize aesthetic losses. The policy now requires detailed geotechnical investigations for potentially unstable areas and careful selection of building sites. It also motivates the development and implementation of slope stabilization measures (Stepanek and Rodier, 1980).

2.2.3 Other Municipalities

In other municipalities in Alberta, setback policies are less specific. In some cases, there are no setback requirements. Until February 1990, subdivision approval was granted by the City of Grande Prairie if the setback requirements for the front yards were met. The back yards of lots ended at the crest of the valley and landowners could build to their property line. Section 3.22 of the new bylaw, states that all buildings within 60 m of the valley crest must be set back 7.6 m and can be no higher than 5 m. The building height can be increased 0.3 m for each additional 3 m setback. At the discretion of the City, an engineering analysis may also be required.

2.3 Summary

This brief survey of setback policies in the province indicates they are not consistent among municipalities. Although the City of Edmonton has the most comprehensive top

of the bank Bylaw Policy, the setbacks are not rationally based. Edmonton does not distinguish between active and abandoned slopes, the two having very different regression potentials. The minimum setback requirement of 7.5 m plus the width of a top of bank roadway (approximately 8 m) is comparable with the setback distance suggested by Tedder (1986) for abandoned slopes. For active slopes however, the Edmonton Policy is not conservative enough. In accordance with the Policy guidelines, the Cruden, Tedder, and Thomson (1989) model would always recommend that there be a geotechnical study for active slopes. As the Edmonton Policy does not indicate when a geotechnical study is necessary, the model can provide planning officers with the necessary criterion.

In general, current practices for delineating setback lines for structures can be improved. Setbacks at specific sites are without a rational basis. Site specific geotechnical studies are necessary to provide information on the stability of slopes that will help establish minimum setback distances. However, because complete geotechnical analyses are too expensive to be used for every lot, it would be preferable to have a less costly and more rapid assessment of the slope. The Cruden, Tedder, and Thomson (1989) model is a simple but effective evaluation of the net regression likely to occur with a given slope. It is therefore a useful method of establishing a preliminary development setback line. If the developer then wishes to develop within the recommended setback distance, then detailed geotechnical studies can be done at the developer's expense.

Geotechnical analyses can only be used as indicators of slope stability because the Factor of Safety obtained from a stability analysis of a slope is not an absolute number. It is, however, a reliable indication of the state of the slope with regard to failure by landsliding. The effect of slope stabilization measures, such as lowering the piezometric

surface or creating a berm at the toe of the slope, can be confidently assessed by stability analysis. The developer considering geotechnical analyses should be prepared to construct works, such as drains or a toe load or armour, to ensure stability of the slope. A detailed site investigation would probably confirm the development line established by the proposed model, not improve on it. If the developer is willing to incur the additional costs of construction, then a site investigation would be of value in guiding the design of the remedial works.

3.0 NATURE AND EXTENT OF THE PROBLEM

Landslides occur along most major rivers in Alberta. A report prepared for the Design and Construction Branch of Alberta Environment (Cruden et al., 1990) clearly indicates the extent and significance of the landslide problem in Alberta. The project began in 1970 with the mapping of landslide incidence along major river valleys in Alberta. The Alberta Landslide Inventory has evolved from the initial mapping project. To date, 100 historic landslides have been recorded for Alberta. Of these, at least 20 have threatened or caused damage to structures.

3.1 The Problem

As the province of Alberta consists largely of relatively flat and featureless plains, the major river valleys and their tributary valleys are the most significant topographic features. The land adjacent to these valleys is therefore highly valued. Riverside cities in Alberta have a significant portion of potentially developable land adjacent to the valleys. But in a detailed urban geology report for the City of Edmonton, Kathol and McPherson (1975) designated a strip of land on either side of the North Saskatchewan River as unsuitable for construction. This strip, along the

length of the river and including the valley slopes, is on an average about 200 m wide, or about 3.8 times the valley depth. This area (Area 1, Figure 36, Kathol and McPherson, 1975) not surprisingly coincides with the area that has the highest susceptibility to erosion (Area 1, Figure 41, Kathol and McPherson, 1975), and with the area that has the highest susceptibility to slumping (Area 1, Figure 42, Kathol and McPherson, 1975). The North Saskatchewan River flows through the City of Edmonton for more than 35 km. Therefore, according to Kathol and McPherson's (1975) designation, an area of approximately 7 km^2 is classified as unsuitable for construction. This amount does not include other areas along tributary valleys such as those that contain Whitemud Creek, Blackmud Creek, Mill Creek, and other smaller tributary creeks. If the same constant, 3.8 times the valley depth, is applied to river valleys in other Alberta cities, a significant area would be classified as unsuitable for construction. For instance, an area of approximately 7.6 km^2 along the Bow River in Calgary would be classified as unsuitable for construction. A significant area along the Elbow River would also be affected. Development in the City of Lethbridge would be restricted by an 11 km stretch of the Oldman River, development in the City of Red Deer would be restricted by a 10.5 km stretch of the Red Deer River, and development in Medicine Hat would be restricted by a 15 km stretch of the South Saskatchewan River.

Valleys with different groundwater conditions, slope geometry, and geology will have different stability conditions which will affect the width of the area designated as unsuitable for construction. Cumulatively however, there is a significant area of land that has considerable limitations for development. Because the land adjacent to the valley systems is at a premium, safe, efficient management is essential. Areas adjacent to slopes that are susceptible to failure should be protected from the

deleterious effects of urbanization or stabilized, while areas adjacent to stable slopes can be developed, optimizing land use options in the area.

3.2 Causes

Landslides frequently occur in urban areas. Thomson and Yacyshyn (1977) have documented that approximately 75 percent of the landslides in Edmonton are triggered by some form of human activity. A significant effect of urban development is the rise of the groundwater table. Reports have shown that rises in the groundwater level can result from leaky storm sewers, irrigation systems, water reservoirs (swimming pools, dug outs), and from weeping tile fields adjacent to slopes (Hamilton and Tao, 1977; MacKay and Thomson, 1980; Ruban and Thomson, 1983; and Thomson and Tiedemann, 1982). Increases in the groundwater levels result in increased internal pressures and a decrease in slope stability. Other potentially detrimental effects of site development are changes in the load conditions of a slope (Ruban and Thomson, 1983; Thomson and Tiedemann, 1982; Townsend and Thomson, 1980), cutting of vegetation, and increased runoff. Unstable load conditions are created when there is dumping of fill or debris over the valley crest or excavations near the toe.

3.3 Extent

The Alberta Landslide Inventory is limited to those landslides for which there are published accounts of location and date of occurrence, hence, there are many historic landslides in the province that have not been included in the list. Consequently, it is likely that there are considerably more than 20 landslides that have either threatened or damaged structures in the province.

In 1973 Alberta Environment appointed R.M. Hardy and Associates to assess slope stability along Whitemud Creek and its tributaries. This area in west Edmonton was essentially undeveloped at the time of the investigation. The study was to assess the current valley characteristics, to assess the impact of proposed changes (urbanization), to recommend measures for bank stabilization and to present guidelines to prevent any further deterioration (Townsend and Thomson, 1980).

In this extensive study, R.M. Hardy and Associates Ltd. (1974) identified more than 45 unstable slopes, of which, 30 were movements that would eventually intersect the top of the ravine. Many of the unstable slopes affected existing housing structures. Ironically, it was often the structures themselves that induced the failures.

In another extensive slope stability study, Tedder (1986) mapped slope movements and developed setback guidelines for a section of the North Saskatchewan River between the expanding urban areas of Edmonton and Fort Saskatchewan. Of the 45 slope movements identified, 6 occurred below homesteads or farmsteads. Tedder (1986) concluded that the initiation of these movements could generally be attributed to the construction of houses and farm buildings. Also, with continued seepage and uncontrolled downslope drainage, Tedder (1986) suggested that most of the slope movements would eventually encroach upon the houses and/or associated buildings.

A report on slope instability along the South Saskatchewan River and its tributaries in the vicinity of Medicine Hat was prepared by MacKay and Thomson (1980) for Alberta Environment. From this report it is evident that at least two landslides (the 1st Street Landslide and the Kingsway Avenue Landslide) have affected nearby structures.

A similar report was completed for the Oldman River and its tributaries in the vicinity of Lethbridge (Ruban and

Thomson, 1983). It was suspected that several of the slide areas were initiated by anthropogenic causes.

A report summarizing case histories spanning 30 years of slope stabilization in Calgary includes 7 major slides, and numerous smaller slides (Hardy et al., 1980). In this report it was evident that although each case has a different geologic setting, they have in common the fact that they were influenced, and in some cases triggered, by activities associated with urban development. During the last decade, slope movements have been much less frequent, primarily because of the development guidelines implemented by the City of Calgary.

Other reports (Hardy and Associates, 1970; Kirby, 1975; Martin et al., 1984; McConnell and Brock, 1904; Prowse, 1977; Stepanek and Rodier, 1980; Thomson, 1971; Thomson and Tiedman, 1982; Thomson and Townsend, 1979; and Thomson and Yacyshyn, 1977) indicate that there are numerous cases of structural damage caused by landslides, many of which were a consequence of the development. A cause and effect situation exists. It is clear that setbacks are necessary to protect the slope from the deleterious effects of developments, and vice versa, to protect the structures from damage caused by slope movements.

4.0 CASE HISTORIES

Ten examples of structural damage caused by landslides have been selected as case histories (listed alphabetically in Table 1) that were used to test the Cruden, Tedder, and Thomson (1989) model of determining setbacks. Potential case histories were identified primarily through an extensive literature search which included published reports, University of Alberta reviews, theses, and documents from the Alberta Environment Library. Government offices, both local and regional, were visited and inquiries were made regarding structures that were damaged by

Table 1: Case Histories of Landslides Causing Damage to Structures

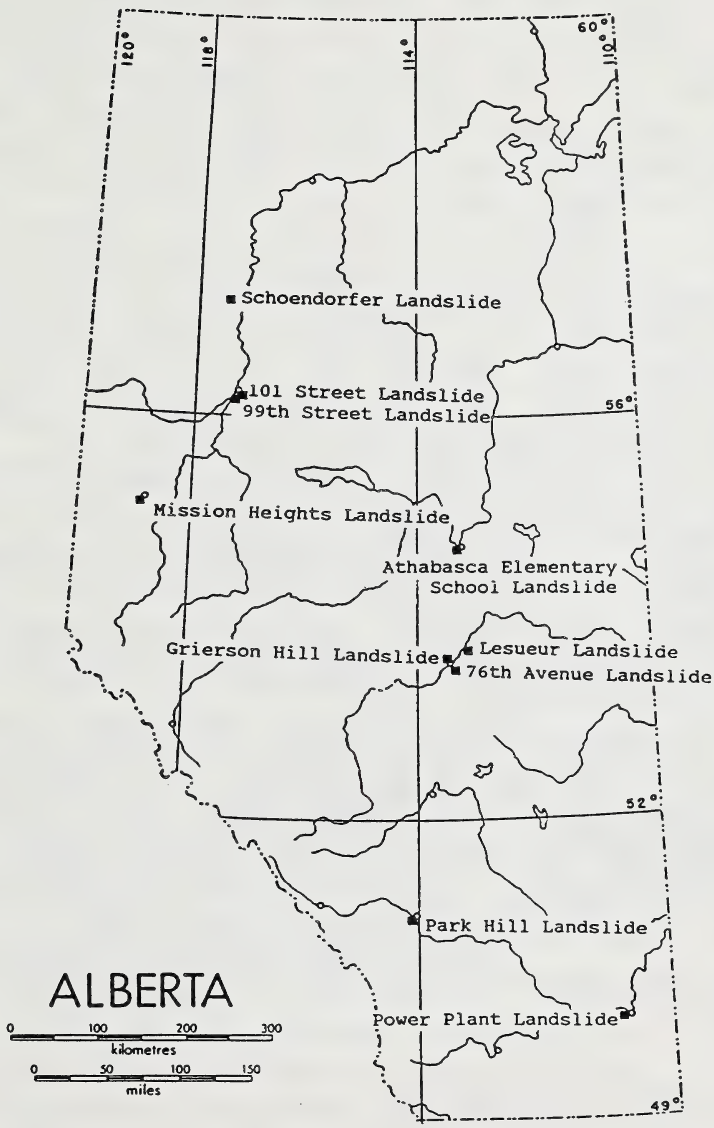
Case History	Location	Year	Damage
1. 101 Street Landslide	Peace River	1987	1 house
2. 76th Avenue Landslide	Edmonton	1972	3 houses
3. 99th Street Landslide	Peace River	1989	2 houses
4. Athabasca Elementary School Landslide	Athabasca	1970	1 school, 6 houses
5. Grierson Hill Landslide	Edmonton	1901+	16 bldgs.
6. Lesueur Landslide	Edmonton	1963	1 house
7. Mission Heights Landslide	Grande Prairie	1990	2 houses
8. Park Hill Landslide	Calgary	1967	1 house
9. Power Plant Landslide	Medicine Hat	1980	2 poles
10. Schoendorfer Landslide	Manning	1990	1 garage

landslide activity.

The distribution of landslides in the province was the preliminary criterion used in the selection of the 10 case studies (Figure 3). As the majority of landslides have occurred in the northern half of the province, 5 of the cases are from northern Alberta. Because many landslides have occurred in or near the City of Edmonton, 3 case studies are from the Edmonton area. Fewer damaging landslides were identified in southern Alberta, but 2 examples have been selected, one from Calgary, and one from Medicine Hat. Urban centres have been selected for the case studies for several reasons; further development is likely to take place, developments often induce landslides, and, already high real estate values are likely to increase.

A third, and more specific criterion used in the selection of the case histories was the availability of information necessary for the analysis. In order to determine the potential regression of the crest of an active slope the ultimate angle of stability must be known. This angle is obtained from abandoned slopes with the same geological and groundwater conditions as the failed slope. Ideally, these slopes should be located in the vicinity of the slope movement. As most river reaches will have both

Figure 3: Location of Case Histories



active and abandoned slopes, there are usually abandoned slopes in the vicinity that can be used for the analyses.

Lastly, the case studies were selected to be as representative as possible. The circumstances affecting each of the landslides and the associated damage differed for each case. Reviewing one of the oldest documented landslides (the Grierson Hill Landslide) and some of the most recent damaging landslides (the Schoendorfer and the Mission Heights Landslides) provides a historical perspective. As this study is primarily concerned with setbacks from slope crests, 9 of the 10 case studies involve structures that have been threatened or damaged by slope movements below them. However, as a useful extension of the model, one case study, the 99th Street Landslide in Peace River Town, looks at the need of a "setforward" for structures that are built too close to the base of the slope. There are several cases in Alberta in which buildings have been threatened or damaged by slope movements from above.

Each of the case histories was examined in detail to determine the topographic conditions at the time of movement, the effect of river erosion, the extent of change, land use in the vicinity of the movement, and representative ultimate slope angles. The Cruden, Tedder, and Thomson (1989) model was then applied to determine the setback guideline for each case. The results were compared with the extent of change resulting from the slope movement. The attributes and effects of the model were then reviewed and evaluated.

4.1 Analysis and Evaluation

The height of the slope (Hs) and the angle of the oversteepened slope (α) at the time of movement was determined for each case history. This information was obtained through consultant reports, available literature,

and measurements taken from orthophotos. Abandoned slopes in the vicinity were located by means of orthophotos, and in some cases by field investigations. Three abandoned slopes were located for each case history and were averaged to provide an estimate of the ultimate slope angle. In most cases, the abandoned slopes were located above a low level terrace, and often had a mature tree cover.

Rate of bank erosion depends on both the properties of the bank material and the nature of the flow of the river. Thomson and Townsend (1979) have made site specific estimates of erosion rates by comparison with historic maps and photographs of the North Saskatchewan River in Edmonton. They have suggested rates of 30 cm/year as an average over a 100 year period. This rate is probably the correct order of magnitude, erosion is however episodic and much larger rates may be encountered in any given year as a result of high flows. Tedder (1986) used this rate over a 50 year period as the value of net lateral river erosion (En). In this study, those slopes subjected to toe erosion, will in most cases be given an En value of 15 m. In some cases it was clear that there was a smaller amount of net lateral river erosion.

Geology and groundwater conditions were recorded for each site. Cruden et al. (1989) suggested the use of three slope categories, based on the simplified stratigraphy and groundwater pressure conditions (Table 2). Any evidence of the groundwater conditions, such as seeps, springs, or ponding was recorded for each case history.

As the landslides used in this study as case histories are recorded in the Alberta Landslide Inventory, the information compiled in the Landslide Report has been printed and included in this report (Appendix A). The Report provides information on the location of the landslide, its elevation and dimensions, the type of landslide, and the damage caused by the landslide.

Table 2: Slope Categories (Cruden et al., 1989)

Category	Groundwater Table (Hw) in relation to Slope Height (Hs)	Simplified Stratigraphy
1. Overburden	Hw = 0	overburden/bedrock contact below river level
2. Bedrock-based	Hw = 1/2 Hs	overburden/bedrock contact in the lower half of the slope
3. Bedrock	Hw = 1/4 Hs	overburden/bedrock contact in the upper half of the slope.

The details for active and abandoned slopes have been compiled in reports entitled "Setback Details" in Appendix B. These reports are in two parts, the first providing details of the active slope, and the second providing details of the abandoned slopes. The landslide is identified by its name, and by the event number as listed in the Alberta Landslide Inventory. Information on the local geology, the groundwater conditions, the slope type, and the damage to structures caused by the landslide has been included in the first section of the report. The second section of the report has information on the location and characteristics of the abandoned slopes and the derivation of the setback guideline based on the Cruden, Tedder, and Thomson (1989) model. The location of the houses relative to the slope crest was determined with the use of air photographs. Each situation is schematically sketched on the third page of this report. Also included is a list of references and a comments section. Table 4 is a summary of the information provided by these reports.

4.1.1 101 Street Landslide, Peace River Town

The two case histories in the Town of Peace River are chosen from a number of slope instability problems faced by the town. Initially the town was built on the low level terrace along the Peace River. However, the terrace pinched out southward and by the late 1960s, development encroached on the valley walls. According to Barlow et al. (1990), little geotechnical work had been done prior to development.

The 101 Street Landslide, occurred in 1987 and affected the house adjacent to its south flank. The main scarp of the slide was within 2 m of 101 Street, and within 6 m of the nearest residence. This landslide was triggered by heavy rains although unstable conditions existed prior to failure. Many of the landslides in this area are a result of a combination of adverse site conditions and site grading activities undertaken by the developer (Barlow et al., 1990). In this particular case, the slope regrading activities of the 1960's reactivated the slide. In the late 1960's up to 5 m of soil was excavated from the toe for the widening of 99 Street, and in 1968 up to 7 m of fill was placed at the crest of the slope during subdivision development.

In the area of the slope movement, fill overlies till, which overlies sands and gravels. The underlying bedrock is competent indurated Cretaceous sandstone. The slope is classified as an overburden slope, so the groundwater level might be expected to be at or below the base of the slope.

The oversteepened slope had a height of 30 m and an inclination of 32°. The ultimate angle of stability was calculated to be 24°. This produced a potential long term regression estimate of 19 m. In this case, since the river is not at the base of the slope, the setback guideline is also 19 m.

4.1.2 76th Avenue Landslide, Edmonton

The second case history, the 76th Avenue Landslide, occurred on 76 Avenue near 88 Street in Edmonton and resulted in the destruction of 3 houses. A tributary of the North Saskatchewan River, Mill Creek, had eroded through glacial lake sediments and till to the clay shale bedrock. Initially there were only a few houses along the crest of this slope, but during the decade following World War II the surrounding area was developed. With this development, the detrimental effects of urbanization affected slope stability. In 1972 a landslide occurred and a graben formed at the crest of the slope. The scarp was tangent to the foundations of the westerly house, passed behind the middle house, and curved downhill under about a quarter of the easterly house (Thomson and Tiedeman, 1982). All three homes were considered unsafe for occupancy and were bought by the city. The houses were then razed and the slope was flattened.

This slope is classified as an overburden slope, consisting primarily of lake sediments and till. The natural groundwater level is therefore presumed to be at or below the base of the slope. The slide was not investigated in detail but as there was little toe erosion and steepening of the slope, a major factor may have been an increase in the groundwater level within the slope due to local irrigation (Hamilton and Tao, 1977).

The oversteepened slope had a height of 12 m and an inclination of 12.5°. The ultimate angle of stability was calculated to be only slightly less at 11.5°. The potential long term regression was estimated to be 5 m. As the creek may not have been actively eroding the toe of the slope, 8 m of net lateral river erosion was added to produce a setback guideline of about 13 m.

4.1.3 99th Street Landslide, Peace River Town

The second landslide example from Peace River Town occurred in the same residential subdivision two years later. This case history is different from the other case histories in that the houses damaged by the landslide were at the base of the slope. The slope movement is likely a response to the oversteepening of the slope behind the houses to increase the depth of the lot. A further factor likely was the infilling of a small ravine. Retaining walls behind the houses were damaged, and the northernmost house was pushed off its foundations.

Till overlies sands and gravels, which overlie the competent Cretaceous sandstone (Barlow et al., 1990). The failure also exposed areas of fill. This slope is classified as an overburden slope, indicating that the groundwater level would be expected to be at or below the base of the slope.

The oversteepened slope had a height of 12 m and an inclination of 31°. The ultimate angle of stability was calculated to be 24°. The potential long term regression was therefore estimated to be 7 m. Based on our experience of the advance of the toe area in landslides in the overburden and mudstones of Alberta, it has been assumed that the run-out at the toe is equal to the loss at the scarp. This value can be used as the "setforward" guideline for the houses at the base of the slope. Following the Cruden, Tedder, and Thomson (1989) model, development at the base of the slope would be setforward 7 m.

4.1.4 Athabasca Elementary School Landslide

The northwest corner of Athabasca Elementary School was damaged by a landslide in 1968 to the extent that this part of the school had to be demolished. The thirteen residences along both sides of Davis Street immediately north of the

school were examined for damage. It was found that the seven houses on the east side of the street had not been damaged by the slide, while the six houses on the west side of the street had all been damaged to some extent. The northernmost house (adjacent to Morgan Avenue) was abandoned, as the distortion of the superstructure was too severe to consider salvaging (Hardy and Associates, 1970). It was also necessary to replace the gas service connection to these houses with flexible hoses.

It is believed that this major landslide was initiated when Muskeg Creek (originally named Spring Creek) began down-cutting rapidly following similar rapid down-cutting of the Athabasca River. When the erosion reached a critical depth, massive landsliding took place, possibly along deep zones of weakness or bedding planes in the clay shale bedrock. The creek is now eroding material along the outside of meanders at only a slow rate, but this is sufficient to continue to cause movement of the landslide along the original surfaces of rupture (Hardy and Associates, 1970). Also contributing to the active state of the landslide is the poor natural surface and sub-surface drainage in the area, which has led to a high groundwater level.

The clay shale bedrock in the area is overlain by thin glacial, glaciofluvial, and glaciolacustrine deposits (Richard, 1987). This is a bedrock slope with the groundwater level estimated at about a quarter of the slope height. The groundwater level is evidenced by the many visible springs and areas of ponded water.

The oversteepened slope had a height of 23 m and an inclination of about 8°. The ultimate angle of stability was calculated to be 7.5°. This produces a potential long term regression estimate of 11 m. As there is little erosion at the toe of the slope, 8 m was added to the regression estimate. With lateral river erosion the setback guideline is 19 m.

4.1.5 Grierson Hill Landslide

The Grierson Hill Landslide occurred in 1901 and has been followed by a series of retrogressive movements since then. During the first event, seven buildings, 1 stable and 6 houses were damaged. By 1915 a total of 16 structures, 2 stables and 14 houses, were affected by the Grierson Hill Landslide. In some cases, threatened houses were relocated before they were actually damaged. Movements continue today, limiting development and necessitating frequent maintenance of Grierson Hill Road.

Coal mining in the vicinity of Grierson Hill is considered to be the primary cause of the 1901 landslide. Subsidence above the workings would have resulted in significant weakening of the backscarp and facilitated subsequent softening (Martin et al., 1984). Another factor was the high precipitation of the early 1900's (The Edmonton Bulletin, 1901).

It is believed that water pressure in cracks and fissures has had a major role in re-activating the slide (Martin et al., 1984). In the 1950s, a significant amount of water was pumped out of the Humberstone mine which was located directly underneath the slide area. From 1911 to 1915, the lower portion of the slope was used as a dump, accumulating up to 15 m of garbage, straw, bricks, clay, and fill etc. (Pennell, 1969). The slope modifications that resulted from the extensive dumping and backfilling caused additional large slope movements. River erosion has been extreme in the area. Between 1887 and 1893 the river encroached into the bank about 15 m (Pennell, 1969). Since that time, the outward movement of the slide and the placement of fill at the toe of the slope has pushed the river out to a maximum of 122 m from its 1893 position (Pennell, 1969).

The geology of the area consists of a clay overlying a clay till layer which overlies the bedrock. The Cretaceous

bedrock of the Edmonton Formation is a clay shale with lesser amounts of sandstone and siltstone (Martin et al., 1984). Coal and bentonite seams are in the bedrock below the Humberstone mine. The slope is bedrock-based, with the groundwater level expected in the lower half of the slope.

The oversteepened slope had a height of 50 m and an inclination of 24°. The ultimate angle of stability was determined to be 17°. This produces a potential long term regression of 46 m. Since the North Saskatchewan River is actively eroding the base of the slope, 15 m of net lateral river erosion was added to the 46 m to produce a setback guideline of 61 m.

4.1.6 Lesueur Landslide

The Lesueur Landslide, located on the outside bend of a meander of the North Saskatchewan River about 6.5 km northeast of Edmonton, began as a distinct but small crack in late April of 1963. On September 3, 1963 a major landslide occurred producing a 6 m scarp which exposed part of the foundation of the house. The major factor leading to the landslide was the long term erosion of the protective fluvial terrace at the base of the slope. The trigger was likely the build-up of water pressure within the slope (Thomson, 1971b) and the decrease of soil strength due to valley rebound (Matheson and Thomson, 1973).

Fine glacial lake sands overlie till which overlie Saskatchewan sands and gravels. The underlying bedrock is the Horseshoe Canyon Formation which consists of a clay shale layer, followed by a bentonitic clay shale layer with a bentonite and coal seam, followed by bentonitic sandstone (Thomson, 1971b). The slope is classified as a bedrock-based slope, with a groundwater level likely located in the lower half of the slope. However, as Woods (1973) suggests, the perched water table evident after the slide, may indicate a high pre-slide water level.

The oversteepened slope had a height of 31 m and an inclination of 26°. The ultimate angle of stability was determined to be 15°. This produces a potential long term regression estimate of 52 m. As the North Saskatchewan River is actively eroding the base of this slope, 15 m of net lateral river erosion was added to this value to produce a setback guideline of 67 m.

4.1.7 Mission Heights Landslide

The Mission Heights Landslide, occurred in 1990 in Grande Prairie. The homes in this newly developed subdivision were built in the early to mid eighties. The backyard of the centre house (10105 81 Ave.) was extended by the placement of fill along the crest of the valley wall.

A smaller failure occurred in 1989, prompting one of the two landowners affected by the slide wisely to divert the runoff from the back of his house to the street in front. The larger slide of 1990 occurred after heavy rains and affected two houses, and possibly a third on the right flank of the slide.

Lacustrine sediments were exposed by the failure. The bedrock in the area, the Wapiti Formation, consists of non-marine sandstone, shale, and coal seams (Jones, 1966). The slope was classified as an overburden slope, indicating that the groundwater level would be expected to be at or near the base of the slope.

The oversteepened slope had a height of 10 m and an inclination of 22°. The ultimate angle of stability was calculated to be 13°. This produces a potential long term regression of 19 m. In this case, since the river is not at the base of the slope, the setback guideline is also 19 m.

4.1.8 Park Hill Landslide

The eighth case study, the Park Hill Landslide, occurred in 1967 in southwest Calgary, on the right bank of the Elbow River. A paved road runs parallel to the valley crest and houses front on the street on the side away from the slope. The head scarp of the slide moved across the road to within 2 m of the house closest to the top of the slope. Because only one house was affected by the slide, it was considered most economical to remove the house and to relocate the road (Hardy et al., 1980).

High groundwater pressures are presumed to be the cause of this landslide. The groundwater table was within 1 m of the slope surface (Hardy et al., 1980). This high water level is anomalous. Bulging occurred towards the base of the slope, but did not extend out into the river.

The valley slope in this area consists of lacustrine clayey silt with lenses and layers of sand (Hardy et al., 1980). The slope was classified as an overburden slope, indicating that the groundwater level would be expected to be at or below the base of the slope.

The oversteepened slope had a height of 30 m and an inclination of 20°. The ultimate angle of stability was calculated to be 16°. This produces a potential long term regression estimate of 23 m. With lateral river erosion the setback guideline is 38 m.

4.1.9 Power Plant Landslide

The Power Plant Landslide occurred in 1980, on the south bank of the South Saskatchewan River in Medicine Hat. The failure produced a near vertical 150 m long scarp. Tension cracks developed adjacent to the 10 - 15 m high scarp, indicating that further recession was likely to occur in the relatively near future. Tension cracks formed within

2.4 m of Calgary Power utility poles, necessitating their relocation.

The 1962 air photos indicated that the low level terrace to the east of the slide area extended westward, protecting the toe of the slope below the power poles. By 1980 the terrace had been completely eroded. It is likely the destruction of this terrace that led to the slope failure. MacKay and Thomson (1980) suggest that the main causes of failure are river erosion and groundwater discharge at various points within the slope.

In the area of the slide, a 1.5 m layer of gravel overlies a silty clay till layer. At a depth of about 24 m, at the till/bedrock contact, there is a 20 cm coal seam. The bedrock is a clay shale. The slope is classified as a bedrock slope with the groundwater level expected at about a quarter of the slope height.

The oversteepened slope had a height of 50 m and an inclination of 43°. The ultimate angle of stability was calculated to be 13°. This produces a potential long term regression estimate of 163 m. Because the South Saskatchewan River is actively eroding the base of the slope, 15 m of net lateral river erosion is added to this value to produce a setback guideline of 178 m.

4.1.10 Schoendorfer Landslide

The final case history, the Schoendorfer Landslide, located in the northeast of the Town of Manning, occurred in 1990 and is threatening a garage. The house on the property is built on an abandoned slope while the garage is located on an active meander slope of the Notikewin River. The 1976 air photographs show that a relatively recent slide had occurred directly below where the garage was to be built. It is likely that the erosion at the toe of the slope triggered the slide.

The surficial deposits are glaciolacustrine (Fox, et al., 1987). The bedrock in the area is the Shaftesbury Formation which is a marine, silty shale (Jones, 1966). The slope is classified as an overburden slope, indicating that the groundwater level is expected to be at or near the base of the slope.

The oversteepened slope had a height of 15 m and an inclination of 47°. The ultimate angle of stability was calculated to be 26°. This produces a potential long term regression estimate of 17 m. Because the Notikewin River is actively eroding the base of this slope, 15 m of net lateral river erosion is added to this value to produce a setback guideline of 32 m.

4.2 Land Use Effects of the Setbacks

In some cases, the setbacks generated by the model have a significant effect on the land use in the immediate vicinity of the slope movement. If a decision has been made to stabilize the slope, the land use becomes a matter for the engineers. Remedial works are used to maintain the slope, and in many cases, the pre-existing land use. This is generally the case when the land has already been developed and property values warrant remedial measures.

Land use in the vicinity of the landslide is affected when the slopes are not stabilized. This is seen in four of the case histories; the 99 Street Landslide, the Lesueur Landslide, the Power Plant Landslide, and the Schoendorfer Landslide (Table 3). A setback line, calculated by the Cruden, Tedder, and Thomson (1989) model, can be drawn for each of these examples to indicate the land use changes in the vicinity of the landslide.

Table 3: Stabilized Slopes

Stabilized Slopes	Natural Slopes
1. 101 Street Landslide	1. 99 Street Landslide
2. 76th Avenue Landslide	2. Lesueur Landslide
3. Athabasca Elementary School Landslide	3. Power Plant Landslide
4. Grierson Hill Landslide	4. Schoendorfer Landslide
5. Mission Heights Landslide	
6. Park Hill Landslide	

4.2.1 101 Street Landslide, Peace River Town

The scarp of the 101 Street Landslide ran within 6 m of the house immediately to the south of the failure. This house was built about 12 m from the crest of the slope, within the 19 m setback guideline. Remedial work, now complete, was necessary to prevent the loss of the house and damage to 101 Street.

4.2.2 76th Avenue Landslide, Edmonton

Three houses were affected by the 76th Avenue Landslide in Edmonton. Damage to the east and west houses was caused by the proximity of the scarp, while severe damage to the third house was a result of being actually within the graben of the slide. The east house was built 3 - 5 m from the crest of the slope. The centre house was built below the crest, and the west house was built up to the crest. All three houses were built inside the 13 m setback limit.

The three houses were razed and the slope was flattened to 11°. The remedial works have stabilized the slope, preventing further damage. This area has now become an extension to the Mill Creek Ravine park system.

4.2.3 99th Street Landslide, Peace River Town

Both of the houses affected by the 99th Street Landslide, 11417 and 11421 99 Street, have been built within 5 m of the toe of the slope. These houses therefore fall within the setforward guideline of 7 m. The two houses affected by the landslide were built in 1978, after the four houses to the south were built. From the 1977 air photos it is evident that cuts were necessary to permit construction north of the existing houses.

All the houses built along 99 Street, have virtually no backyards. It is entirely possible that without remedial work, the other houses along this section of 99 Street may be affected by slope movements behind them. Figure 4 illustrates the setforward generated by the model, and its effect on land use in the immediate vicinity of the landslide. In accordance with the Cruden, Tedder, and Thomson (1989) model, about 400 m^2 along the base of the slope behind the three northernmost houses should not be developed. Once the two damaged houses have been removed, the recommended setforward and the setback bylaw regulations will probably preclude subsequent development.

4.2.4 Athabasca Elementary School Landslide

The structures damaged by the Athabasca Elementary School Landslide, have been built on the valley wall. As the overall slope is locally steeper than the ultimate angle of the valley wall the model indicates that construction on the wall is not advisable without remedial works.

The slope has been stabilized. Horizontal drains have been installed and surface water has been diverted. Muskeg Creek has been straightened (eliminating four meanders) and realigned to prevent further erosion of the toe of the slope.

Figure 4: Setforward Guideline for the 99th Street Landslide

4.2.5 Grierson Hill Landslide

The total crest retreat of the Grierson Hill Landslide between 1900 and 1958 was 43 m (Pennell, 1969) which is quite comparable to the potential long term regression of 46 m. It was not possible to determine where the structures were initially located relative to the slope crest, but they were apparently too close.

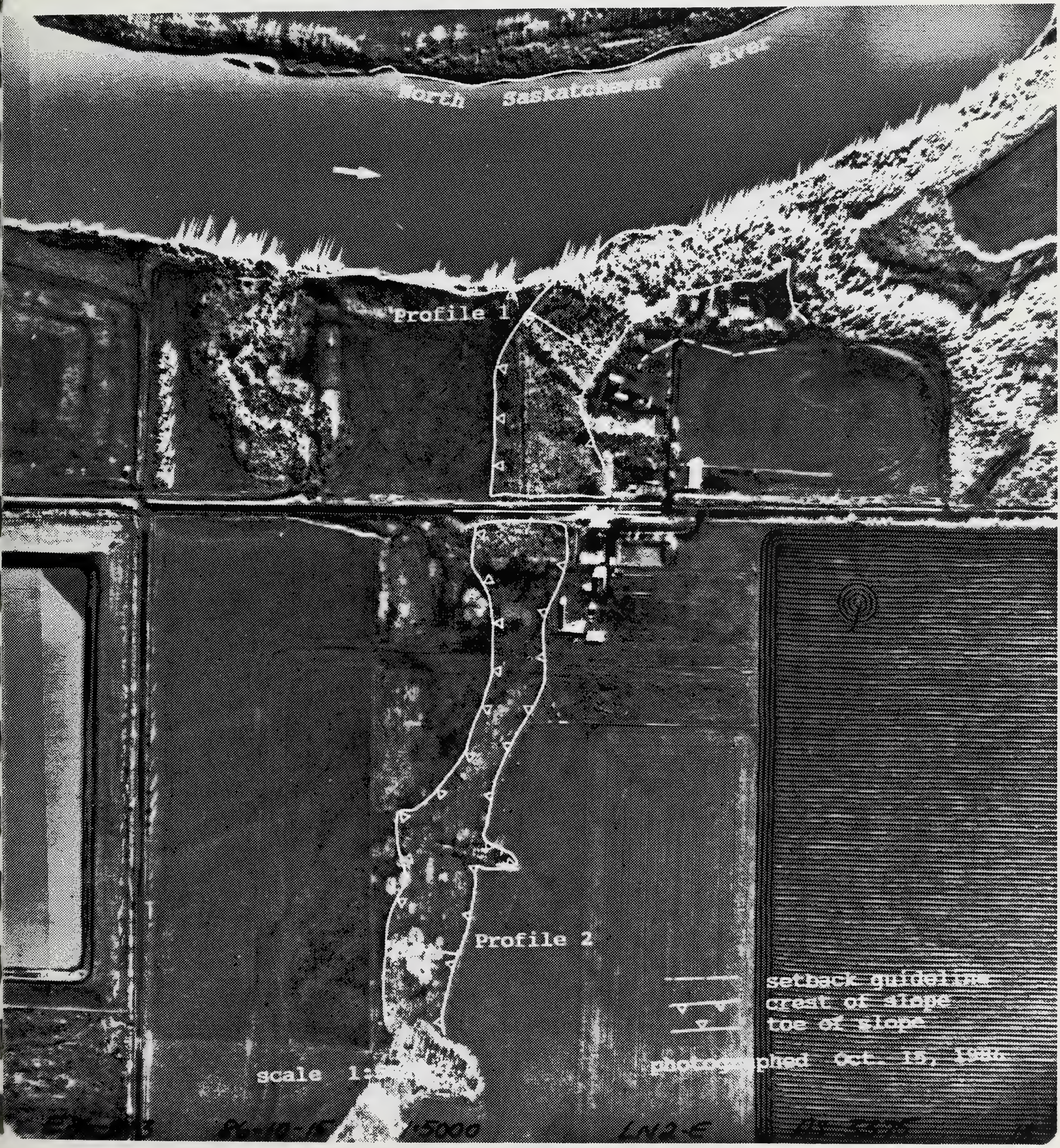
Although the slope is still moving, the rate has significantly decreased. Since the Humberstone mine was pumped and the drains were installed, movements have been small. Fill placed at the toe has also helped stabilize the slope (Pennell, 1969). The Edmonton Convention Centre has been built on the right flank of the slide, but most of the slide area has been designated as parkland.

4.2.6 Lesueur Landslide

As a result of the Lesueur Landslide the slope crest initially retreated about 12 m. During the next seven years the crest retreated another 10 m (Thomson, 1971a), and by 1987 the crest had retreated an additional 1.4 m (Thomson, pers.comm.). The Lesueur house was built about 8 m from the crest, well within the recommended setback limit of 67 m.

In the 24 years since the slide occurred, the crest of the scarp retreated a total of about 23 m suggesting that 67 m is a conservative, but reasonable setback estimate. Figure 5 indicates the setback generated by the model, and its effect on land use in the immediate vicinity of the landslide. Accordingly, development above the valley wall might be restricted for an area of about 9,000 m^2.

Figure 5: Setback Guideline for the Lesueur Landslide



4.2.7 Mission Heights Landslide

The scarp of the Mission Heights Landslide extended up to the centre house (10105 81 Ave.) and was within 3 m of the southwest corner of the second house (10101 81 Ave.). All the structures (including the third house) were built within the setback guideline of 19 m. The house at 10101 81 Avenue was built approximately 10 m back from the crest, and the house at 10105 81 Avenue was built up to the crest.

Remedial work necessary to stabilize the slope has been carried out. The slope has now been flattened and a drainage blanket has been installed. As with the 101 Street Landslide in Peace River Town, the structures affected by the landslide have been maintained as a result of slope remediation.

4.2.8 Park Hill Landslide

The main scarp of the Park Hill Landslide moved across the road to about 2 m in front of the nearest house. The road was initially about 4 m back from the crest and the house was about 14 m back from the crest. Therefore, the road and the house were well within the setback guideline of 38 m.

Stabilization works were necessary for this slope. In 1967 the slope was unloaded and horizontal drains were installed. In 1970 there was further movement and a toe load was added. Since that time the slope has been relatively stable with only minor creep movements.

4.2.9 Power Plant Landslide

When the Power Plant Landslide occurred (1980), the crest retreated about 15 m, although tension cracks extended further back. Both power poles were well within the setback guideline of 178 m. The south power pole was set about 12 m

back from the crest, and the north power pole was set about 18 m back from the crest.

MacKay and Thomson (1980) concluded that this landslide indicates that the valley walls may not be as stable as they appear to be. Therefore, in the absence of a thorough engineering investigation, they recommend that development above the valley walls be setback a distance of 1.5 - 2 times the valley depth. In this case they are recommending a setback distance of 75 - 100 m. The setback guideline using the ultimate angle of the slope is considerably greater (Figure 6). This guideline would restrict development in a 3,200 m^2 area along the crest of the slope.

4.2.10 Schoendorfer Landslide

The crest of the Schoendorfer Landslide is now about 3 m from the garage. The garage was originally built approximately 9 m back from the crest of the slope, well within the setback guideline of 32 m. As the house is safely located further back on an abandoned slope, remedial work is unlikely.

Figure 7 illustrates the setback generated by the model and its effect on land use. In the vicinity of the landslide, development would be restricted in an area of about 2,500 m^2 along the crest of the slope. In order to the save the garage, it will have to be moved.

4.3 Summary

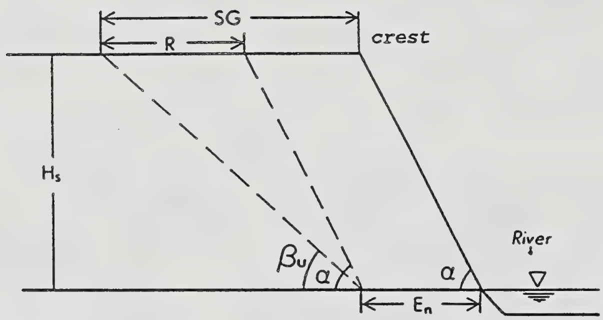
The preceding ten examples of landslides that have caused damage to structures have been used as case histories to test the Cruden, Tedder, and Thomson (1989) model for delineating crest setbacks. Table 4 is a summary of the setback details used the determine the setback guideline for each case history.

Figure 6: Setback Guideline for the Power Plant Landslide

Figure 7: Setback Guideline for the Schoendorfer Landslide

Table 4: Setback details for each case history

Landslide	Hs(m)	ßu(°)	α(°)	R(m)	En(m)	SG(m)
101 Street	30	24	32	19	-	19
76th Avenue	12	11.5	12.5	5	8	13
99th Street	12	24	31	7	-	7
Athabasca	23	7.5	8	11	8	19
Grierson Hill	50	17	24	46	15	61
Lesueur	31	15	26	52	15	67
Mission Heights	10	13	22	19	-	19
Park Hill	30	16	20	23	15	38
Power Plant	50	13	43	163	15	178
Schoendorfer	15	26	47	17	15	32



where:
Hs = height of slope
ßu = ultimate angle of stability
α = inclination of the oversteepened slope
R = potential long term regression
En = net lateral river erosion
SG = setback guideline

In all of ten case studies, the Cruden, Tedder and Thomson (1989) model has delineated setback distances that appear to be prudent and effective guidelines for development (Table 5). The Power Plant Landslide in Medicine Hat has the largest setback distance. This is due to the large difference between the oversteepened slope and the ultimate slope angle. The oversteepened slope is both high (50 m) and steep (43°), while abandoned slopes in the area have obtained a long term stable angle of 13°.

Table 5: Summary Table

Landslide	SG	Distance of Structure From Crest	Approx. Crest Retreat	Comments
101 Street	19 m	12 m	6 m	-remedial work was necessary-gravel key, slope flattening
76th Avenue	13 m	within 5 m	5 m	-3 houses razed, slope flattened
99th Street	7 m	within 5 m	5 m	-at least one of the two houses will have to be removed
Athabasca	19 m	on slope	-	-the model indicates slope remediation was necessary before the structures could be safely built
Grierson Hill	61 m	?	43 m	-16 structures affected; 2 stables, 14 houses, some were moved, others were demolished
Lesueur	66 m	8 m	23 m	-the Lesueur house was removed
Mission Heights	19 m	within 10 m	7 m	-remedial work was necessary-gravel blanket, slope flattening
Park Hill	22 m	14 m	12 m	-the road was relocated and house demolished, remedial work was also necessary-horizontal drains, slope unloading toe load
Power Plant	178 m	within 18 m	16 m	-two power poles had to be moved
Schoendorfer	32 m	9 m	6 m	-the garage may have to be moved

The application of this model has, in all cases, produced a setback guideline that is significantly beyond the position to which the crest retreated. In other words, the extent of change resulting from the slope movements would not have resulted in damage to any structure if development had followed the recommended setback distance. In the cases of the 76th Avenue Landslide and the Grierson Hill Landslide, the total retreat of the crest was just within the calculated R distance (regression). Therefore, the value added for net lateral river erosion is a necessary component, to increase the margin of safety.

In some cases, remedial work was carried out to stabilze the slope below the damaged structures. Slope flattening and drainage measures were most frequently used. Several structures had to be removed because of the severity of the damage caused by the slide. This is the case with the 76 Avenue Landslide, the Athabasca Landslide, the Grierson Hill Landslide, the Lesueur Landslide, and the Park Hill Landslide. At least one house affected by the 99 Street Landslide will also have to be removed and the garage affected by the Schoendorfer Landslide will have to be moved.

In the four cases in which the slopes have not been stabilized, and slope development has followed a natural course, land use in the immediate vicinity of the landslide might well be modified. In general, the effect of setbacks generated by the model might be to restrict development near the slope crest. In all cases, a buffer zone was indicated in order to ensure the long term safety of structures.

5.0 REVIEW AND EVALUATION OF THE MODEL

The Cruden, Tedder, and Thomson (1989) model has proven to be a simple, yet effective method for designating development setbacks. Field measurements of the

oversteepened slope angle and abandoned slope angles can be easily accomplished. Abandoned slopes can best be identified through either air photographs, or orthophotos. The height of the slope, if not measured in the field, can be obtained from available topographic maps.

The model has been validated by the ten case histories. The calculated setback guidelines were in each case well beyond the main scarp of the slide and the damaged structures were generally well within the setback guideline. The correspondence between the predictions of the setback guidelines and reality can only be evaluated after the long term natural flattening of the slope has generated the maximum amount of crest retreat, that is, a stable slope has been achieved. This may take several hundred years.

The extension of the model to calculate a setforward appears to be a reasonable approach. Structures can be built too close to the base of slopes. If the houses affected by the 99 Street Landslide had been built more than 7 m away from the base of the slope, it is likely that they would not have been damaged. Unfortunately, this would probably have violated setbacks from the kerb of 99 Street.

Working through this model for the various case histories has highlighted some areas of concern. Before this project, it was assumed that orthophotos would be available for all municipal areas in the province. Orthophotos are large scale aerial photographic maps with detailed contours. Because of the large scale (1:5000) and the small contour interval (1 m) of these maps, they are the most useful tool in determining topographic details. Although most municipalities have these maps available, three locations, Calgary (Park Hill Landslide), Athabasca (Athabasca Elementary School Landslide), and Manning (Schoendorfer Landslide), did not. Consequently alternative sources of information were required.

Some difficulties were encountered with the measurement of abandoned slopes. As expected, there were usually

several abandoned slopes in the vicinity of the landslide. The selection of three representative slope angles may be difficult. In the Mission Heights case, where six abandoned slopes in the area were measured, four were 13°, one was 11°, and one was 17°. If the higher three angles were averaged, ßu would be 14°, resulting in a setback guideline of 15 m. If the lower three angles were averaged, ßu would be 12°, resulting in a setback guideline of 22 m. This produces a significant 7 m difference in the setback guideline between the two procedures. We believe that the slopes with lower slope angles have been abandoned for a longer period and are therefore more representative of the ultimate angle of stability. Consequently, if the lowest angle abandoned slopes are applied to the model, the setback guideline will be more conservative and unequivocal.

The configuration of the abandoned slopes is also likely to affect the ultimate slope angles. Headlands tend to have lower water tables than do adjacent gullies. Water flow is directed towards the gullies, and away from the headlands. Consequently, the slopes along gullies will likely have a shallower ultimate angle than will those along headlands. Therefore, ultimate slopes should be measured in comparable topographic positions to the proposed development site.

Although the model does incorporate the effects of fluvial erosion at the base of the slope, it does not consider the effects of seepage erosion, or channelized flow within the slope. Both these parameters may contribute considerably to slope regression, affecting the recommended setback distance.

Also, the model does not take into account induced changes to the slope, for example, groundwater level, that often occur as a result of development. The watering of lawns has been considered a problem in urban areas, inducing slope failures in slopes that would otherwise be stable. Therefore consideration may have to be given to increasing

the setback guideline to take into account the adverse affects of development. This, however, would be the subject of future research.

5.1 Summary

The model can be used as a simple and effective method for detemining setback guidelines. The guideline should be drawn by a qualified geotechnical engineer or engineering geologist as part of the municipal planning process. This line can then be used as the basis of a municipal bylaw. As a means of drawing attention to this model we suggest the preparation of material for a one day course at the Faculty of Extension for planners, for a poster and a presentation for technical meetings, and for a paper in a technical journal.

Our experience with the case histories suggests the following to enhance the model:

1. The ultimate angle of stability should be estimated from ultimate slopes within 1 km of the slope under consideration. An average of the three lowest angle ultimate slopes within this distance guards against local variations.

2. Abandoned slope angles should be derived from the measurement of slopes in similar topographic and geologic settings, that is, measurements should be made at headlands for headland developments, and at gullies for developments back from gullies.

The model in its current form is both simple to use and effective within its limitations. In other circumstances, a detailed site investigation may still be necessary. Such is the case if natural seepage erosion or channelized flow is evident on the slope. Erosion due to these causes may be

significant and should therefore be incorporated into the estimate of slope regression.

The orientation of the ground surface beyond the crest of the slope should also be taken into consideration. The model is only applicable to surfaces that are approximately horizontal. If the ground surface beyond the crest rises, the setback guideline will be greater than that calculated for level ground. Similarily, if the ground slopes away from the crest, the setback will be less than that for a horizontal surface.

The following are suggestions for further research.

1. Post-development changes to the groundwater level can adversely affect slope stability. In those cases where post-development groundwater is likely to raise the natural level significantly, provision should be made in the determination of the setback. A higher groundwater level results in lower ultimate slope angles. Research in this area would more clearly indicate the response of slopes to significant changes in the groundwater level. If abandoned slopes with similar groundwater levels to the anticipated post development levels can be found, their angles should be measured and incorporated into the model. This procedure is particularly appropriate when natural groundwater levels are low, as was the case with the Peace River landslides. When adequate piezometric data are not available, a groundwater evaluation may be necessary prior to the development of any facility likely to add significant quantities of water to a slope.

2. Case histories are extremely valuable. Municipalities should be encouraged to report relevant details to the Alberta Landslide Inventory. Further case histories, particularily those with a full geotechnical investigation, would bolster confidence in the method,

verify the model, and increase the range of circumstances in which the model can be effectively applied.

3. Although 30 m / 100 years is considered a reasonable estimate for the rate of river erosion, there will be site to site variations. Until more information is available, this estimate can be used as a measurement for net lateral river erosion. However, this does appear to be a major gap in the river engineering knowledge base in the Province and an obvious concern for the Province's riverside communities. We would recommend that the Research Council of Alberta, these communities, and Alberta Environment be encouraged to monitor study sections of their rivers with a view to enhancing knowledge of river erosion. Site specific rates of net lateral river erosion can then be applied to the model.

To summarize, the research conducted for this report indicates that the model, in its current form, is effective, and has a broad range of application. However, in some circumstances, the use of the model should be qualified. Such circumstances include those cases in which there is evidence of seepage or channel erosion on the slope, when the surface beyond the crest of the slope is not approximately horizontal, or when significant post-development changes in the groundwater level are anticipated. With these refinements and more site specific erosion estimates, the model will still be relatively simple to use, but the setbacks will be more site specific and, the applicability of the model can then be extended to a much wider range of circumstances.

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APPENDIX A: LANDSLIDE REPORTS

LANDSLIDE REPORT

Name of Landslide: 101 Street Slide, Peace River Town   Event No.: 76

Latitude: 56 13 05   Longitude: 117 16 53

Elevation: crown 362 m a.s.l.

tip 334 m a.s.l.

Date of Occurrence: 1987   Type of Landslide: earth slide

Size:			
Length	Lr =53 m	Ld = 70 m	L = 70 m
Width	Wr =120 m	Wd = 115 m	
Depth	Dr =14 m	Dd = 12 m	

Damage: 1 house and 101 Street threatened

References:

1. Barlow, P., McRoberts, E., and Tenove, R., 1990. Stabilization of urban landslides in Peace River, Alberta. 43rd Canadian Geotechnical Conference. Canadian Geotechnical Society, Toronto.

2.

3.

Comments:

- a pre-existing failure plane in the clay shale was reactivated by slope regrading activities in the late 1960's when up to 5 m of soil was excavated from the toe for the widening of 99 St., and, during subdivision development in 1968 when up to 7 m of fill was placed at the crest of the slope (Barlow et al., 1990)

Appendix A: continued

LANDSLIDE REPORT

Name of Landslide: 76th Ave. at Mill Creek, Edmonton   Event No.: 17

Latitude: 53 30 45   Longitude: 113 27 55

Elevation: crown 671 m a.s.l.

tip 659 m a.s.l.

Date of Occurrence: 1972   Type of Landslide: earth slide

Size:	Length	Lr =60 m	Ld =	60 m	L =	65 m
	Width	Wr =90 m	Wd =	85 m		
	Depth	Dr = - m	Dd =	- m		

Damage: 3 houses damaged; bought, then razed by the City of Edmonton

References:

1. Thomson, S. and Tiedmann, C.E., 1982. A review of factors affecting landslides in urban areas. Bulletin of the Association of Engineering Geologists. 19: 55-65.

2.

3.

Comments:

- the main scarp was tangent to the foundation of the westerly house, passed uphill of the middle house, and arced downhill under about a quarter of the easterly house

- the downhill edge of the graben passed in front of the middle house, severly distorting it

- the houses front onto 77 Ave.

Appendix A: continued

LANDSLIDE REPORT

Name of Landslide: 99 St. Slide, Peace River Town Event No.: 75

Latitude: 56 13 15 Longitude: 117 16 50

Elevation: crown 366 m a.s.l.

tip 334 m a.s.l.

Date of Occurrence: 22 05 1989 Type of Landslide: earth slide

Size:	Length Lr = - m	Ld = 20 m	L = 23 m
	Width Wr =35 m	Wd = 35 m	
	Depth Dr = - m	Dd = - m	

Damage: 2 houses damaged (11417 99 St. and 11421 99 St.)

References:

1. Rod Burr, Surface Water, Alberta Environment, Peace River Town

2.

3.

Comments:

- slope behind houses was cut - also evidence of fill

- 11417 99 St. has lost the retaining wall, and the house has been pushed off its foundations (house bought by the City)

- 11421 99 St. and 11425 99 St. - the retaining wall is cracked and tilted

- first signs of movement - Nov. 5, 1988, and gas lines broke - Nov. 9, 1988

LANDSLIDE REPORT

Name of Landslide: Athabasca Elementary School Slide Event No.: 52

Latitude: 54 43 07 Longitude: 113 17 42

Elevation: crown 540 m a.s.l.

tip 515 m a.s.l.

Date of Occurrence: 1968 Type of Landslide: rock slide

Size:	Length Lr = - m	Ld = 214 m	L = 214 m
	Width Wr =335 m	Wd = 335 m	
	Depth Dr = - m	Dd = - m	

Damage: N.W. corner of school, 6 houses N. of school (1 abandoned)

References:

1. Hardy R.M. and Associates Ltd., 1970. Athabasca Elementary School and vicinity proposed comprehensive area stabilization. Hardy and Associates Report no. E-1843. Edmonton. 15 p.

2.

3.

Comments:

- Northwest Survey Corporation prepared contour maps of the entire area from recent aerial photographs

- previous reports by Hardy and Associates - E-1842, April 25, 1969; E-1843, July 14, 1969; E-1843, August 14, 1969; E-1843, November 25, 1969

LANDSLIDE REPORT

Name of Landslide: Grierson Hill Slide, Edmonton   Event No.: 12

Latitude: 53 32 30   Longitude: 113 29 30

Elevation: crown 655 m a.s.l.

tip 603 m a.s.l.

Date of Occurrence: 1901   Type of Landslide: rock slide

Size:				
	Length	Lr =255 m	Ld = 274 m	L = 274 m
	Width	Wr =500 m	Wd = 500 m	
	Depth	Dr =31 m	Dd = 23 m	

Damage: 1901- 7 structures, by 1907- 4 structures, by 1915- 5 structures

References:

1. Martin, R.L., Williams, E.R., Balanko, L.A., 1984. The Grierson Hill Slide, Edmonton, Alberta. 37th Canadian Geotechnical Conference. Canadian Geotechnical Society, Toronto. pp. 125-133.

2. Poppitt, J.B., 1963. Grierson Hill Stabilization Project, Historical Summary. Report to the City of Edmonton, Edmonton City Archives. 11 p.

3. Pennell, D.G., 1969. Residual strength analysis of five landslides. Ph.D. Thesis, University of Alberta, Edmonton. 166 p.

Comments:

- movement recorded since 1887

- possible causes of initial slide: preceding wet seasons, coal mine activity (Humberstone Mine)

- a total of 16 structures (2 stables and 14 houses) have been damaged by the Grierson Hill landslide

LANDSLIDE REPORT

Name of Landslide: Lesueur Slide, North Sask. R., Edmonton Event No.: 8

Latitude: 53 36 05 Longitude: 113 18 45

Elevation: crown 643 m a.s.l.

tip 610 m a.s.l.

Date of Occurrence: 03 09 1963 Type of Landslide: rock slide

Size:	Length	Lr =70 m	Ld =	70 m	L =	75 m
	Width	Wr =140 m	Wd =	300 m		
	Depth	Dr =17 m	Dd =	15 m		

Damage: 1 house damaged

References:

1. Thomson, S., 1971. The Lesueur Landslide, A failure in Upper Cretaceous clay shale. Proceedings, Ninth Annual Engineering Geology and Soils and Engineering Symposium, Boise, ID. pp. 257-287.

2. Woods, P.J., 1973. A re-analysis of the Lesueur Landslide. M.Eng. report. University of Alberta. 13 p.

3. Pennell, D.G., 1969. Residual strength analysis of five landslides. Ph.d. thesis. University of Alberta, Edmonton. 166 p.

Comments:

- major factor leading to the landslide was the erosion of the terrace

- triggering mechanism - build up of water pressure in the toe area

- an addition to the east side of the house was built in 1960

LANDSLIDE REPORT

Name of Landslide: Mission Heights Slide, Grande Prairie Event No.: 97

Latitude: 55 09 20 Longitude: 118 48 09

Elevation: crown 654 m a.s.l.

tip 644 m a.s.l.

Date of Occurrence: 6 1990 Type of Landslide: earth slide

Size:	Length	Lr = -	m	Ld =	20	m	L =	25	m
	Width	Wr =35	m	Wd =	35	m			
	Depth	Dr =2	m	Dd =	-	m			

Damage: 2 houses threatened and possibly a third

References:

1. Bernd Manz, City Engineer, City of Grande Prairie.

2. Lisaway, homeowner (10105 81 Ave.)

3.

Comments:

- fill placed to extend backyard of Lisaway property

- slide occurred after heavy rains

- first (smaller) slide occurred in 1989 - Lisaway diverted water drainage into road (away from slope)

- Bear Creek backed up water in the culvert, causing water to accumulate in abandoned meander at base of scarp

LANDSLIDE REPORT

Name of Landslide: Park Hill Slide, Calgary   Event No.: 4

Latitude: 51 01 10   Longitude: 114 03 55

Elevation: crown 1065 m a.s.l.

tip 1040 m a.s.l.

Date of Occurrence: 1967   Type of Landslide: earth slide

Size:								
	Length	Lr =87	m	Ld =	85	m	L = 87	m
	Width	Wr =290	m	Wd =	290	m		
	Depth	Dr = -	m	Dd =	-	m		

Damage: road relocated and house removed

References:

1. Hardy, R.M., Clark, J.I., Stepanek, M., 1980. A summary of case histories spanning thirty years of slope stabilization in Calgary, Alberta. In: Slope Stability Problems in Urban Areas. Canadian Geotechnical Society, Toronto. 24 p.

2. Hardy, R.M. and Associates, 1970. Hillside Instability 38 Avenu and 1A Street S.W. Calgary, Alberta. Hardy R.M. and Associates Ltd., Job No. CS 1836, Calgary.

3.

Comments:

- 1967 - stabilization works - minor slope unloading, installation of horizontal drains

- 1970 - more movement - toe load added

- 1990 - stable

LANDSLIDE REPORT

Name of Landslide: Power Plant Slide, Medicine Hat   Event No.: 25

Latitude: 50 02 30   Longitude: 110 43 20

Elevation: crown 706 m a.s.l.

tip 656 m a.s.l.

Date of Occurrence: 22 03 1980   Type of Landslide: rock slide

Size:					
Length	Lr =340 m	Ld =	410 m	L =	445 m
Width	Wr =150 m	Wd =	150 m		
Depth	Dr =38 m	Dd =	32 m		

Damage: tension cracks formed within 2.4 m of Calgary Power utility pole

References:

1. MacKay, C. and Thomson, S., 1980. A report on slope instability along the South Saskatchewan River and tributaries in the vicinity of Medicine Hat, Alberta. Alberta Environment, Edmonton. 123 p.

2.

3.

Comments:

- the initial failure had a crest recession of about 15 m (the tension cracks were further back)

- main causes of failure: river erosion, ground water discharge at various points within the slope profile

LANDSLIDE REPORT

Name of Landslide: Schoendorfer Slide, Manning Event No.: 96

Latitude: 56 55 45 Longitude: 117 37 00

Elevation: crown 472 m a.s.l.

tip 457 m a.s.l.

Date of Occurrence: 6 1990 Type of Landslide: earth slide

Size:	Length	Lr = -	m	Ld =	21	m	L = 21	m
	Width	Wr =15	m	Wd =	15	m		
	Depth	Dr = -	m	Dd =	-	m		

Damage: garage threatened - house safe (located on abandoned meander)

References:

1. Greg Rycroft, Municipal Co-ordinator, Town of Manning.

2.

3.

Comments:

- the garage is located on an active slope of the Notikewin River, while the house is located above an abandoned slope

APPENDIX B: SETBACK DETAILS

SETBACK DETAILS

Active Slope

Name of landslide: 101 Street Slide, Peace River Town Event no.: 76

Street address:

Slope type: overburden

Groundwater evidence:

Geology:

- fill overlies till which overlies sands and gravels
- between the till and the sands and gravels there is a presheared layer of clay shale (Barlow et al., 1990)
- underlying bedrock is competent indurated Cretaceous sandstone (Barlow et al., 1990)

Structures damaged: the scarp was within 2 m of 101 Street and within 6 m of the nearest residence

Date structure was built: about 1968

Date structure was damaged: 1987

SETBACK DETAILS

Abandoned Slopes

At landslide: 101 Street Slide, Peace River Town   Event no.: 76

Profile 1

Location: distance from slide - 140 m
direction from slide - north, same side of Peace R., 101 St. - 99 St.

Characteristics: pre-development slope angle (Barlow et al., 1990)

Groundwater evidence:

Slope angle: 22° (Barlow et al., 1990)

Profile 2

Location: distance from slide - 440 m
direction from slide - north, same side of Peace R., 101 St. - 99 St.

Characteristics: a slope with mature trees

Groundwater evidence:

Slope angle: 24° (field measurement)

Profile 3

Location: distance from slide - 180 m
direction from slide - south, same side of Peace R., 99 St. - river

Characteristics: a slope with a resistant sandstone base

Groundwater evidence:

Slope angle: 26° (field measurement)

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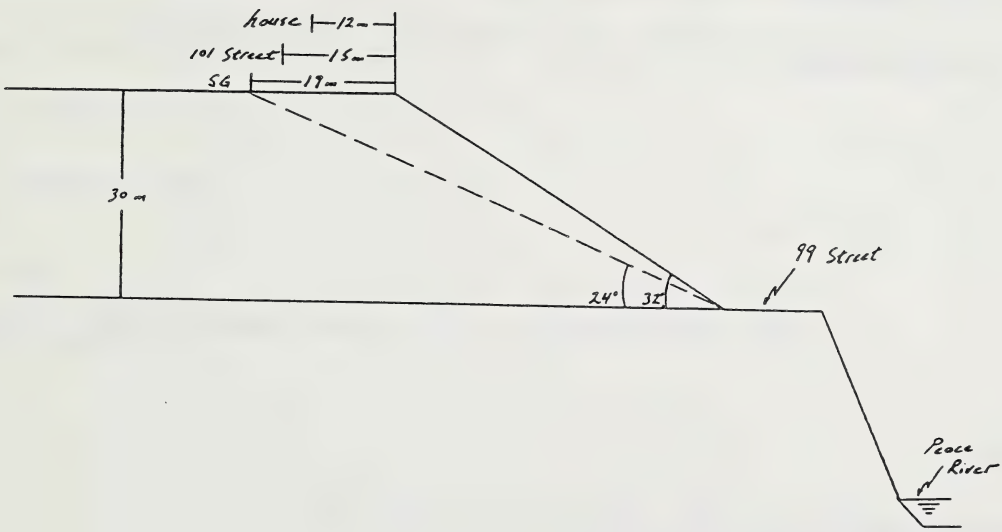
101 Street Slide, Peace River Town



Hs - slope height = 30 m (Barlow et al., 1990)

ßu - ultimate angle of stability = 24°

α - inclination of oversteepened slope

= 32° (Barlow et al., 1990; field measurement)

R - potential long term regression

= Hs/tanßu - Hs/tanα = 19 m

En - net lateral river erosion = not applicable

SG - setback guideline

= R + En = 19 m

References and Comments

References:

1. Barlow, P., McRoberts, E., and Tenove, R., 1990. Stabilization of urban landslides in Peace River, Alberta. 43rd Canadian Geotechnical Conference. Canadian Geotechnical Society, Toronto.

2. Surveys and Mapping Branch, 1977. Peace River (1974) 231-16 in part. Alberta Transportation, Edmonton.

3.

4.

5.

Comments:

- the house immediately to the south of the failure was built about 12 m from the crest of the slope; within the 19 m recommended setback distance

- as the scarp of the failure ran within 6 m of this house and within 2 m of the road, the remedial work, now complete, was necessary to prevent the loss of the house and damage to 101 St.

- it is unlikely, as Barlow et al. (1990) suggest, that a layer of shale overlies a depositional layer of sands and gravels

SETBACK DETAILS

Active Slope

Name of landslide: 76th Ave. at Mill Creek, Edmonton   Event no.: 17

Street address: on 76th Ave. near 88 St.

Slope type: overburden

Groundwater evidence:

Geology:

- glacial lake sediments overlie till, which overlies the clay shale bedrock

Structures damaged: 3 houses

Date structure was built: prior to earliest photographs (1949)

Date structure was damaged: 1972

SETBACK DETAILS

Abandoned Slopes

At landslide: 76th Ave. at Mill Creek, Edmonton   Event no.: 17

Profile 1

Location: distance from slide - 180 m
direction from slide - opposite side of the valley

Characteristics: abandoned meander, large trees present

Groundwater evidence:

Slope angle: 11° (Edmonton orthophoto 928+36)

Profile 2

Location: distance from slide - 500 m
direction from slide - downstream, same side of the valley

Characteristics: abandoned meander, large trees present

Groundwater evidence:

Slope angle: 11° (Edmonton orthophoto 931+36)

Profile 3

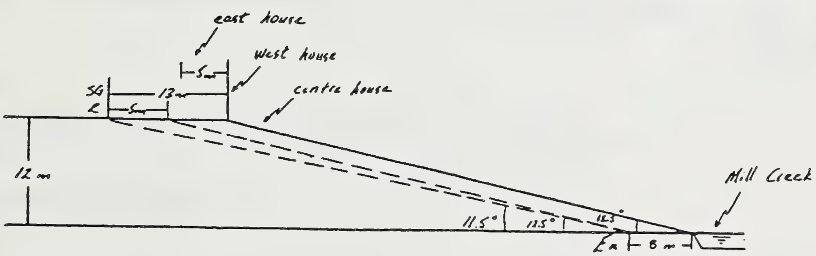
Location: distance from slide - 360 m
direction from slide - upstream, opposite side of the valley

Characteristics: abandoned meander, medium sized trees

Groundwater evidence:

Slope angle: 12.5° (Edmonton orthophoto 928+36)

76th Ave. at Mill Creek, Edmonton



Hs - slope height = 12 m (orthophoto measurement)

βu - ultimate angle of stability = 11.5°

α - inclination of oversteepened slope

= 12.5°(orthophoto measurement)

R - potential long term regression

$= Hs/\tan\beta u - Hs/\tan\alpha = 5$ m

En - net lateral river erosion = 8 m

SG - setback guideline

= R + En = 13 m

References and Comments

References:

1. Thomson, S. and Tiedmann, C.E., 1982. A review of factors affecting landslides in urban areas. Bulletin of the Association of Engineering Geologists. 19: 55-65.

2. Surveys and Mapping Branch, 1962. North Edmonton, Alberta. NTS series 83 H/11d.

3. Transportation Systems Design Dept., 1980. Edmonton 928+36. The City of Edmonton.

4. Transportation Systems Design Dept., 1980. Edmonton 931+36. The City of Edmonton.

5.

Comments:

- damage to the east and west houses was caused by the proximity of the scarp, while the centre house was damaged by being transported by the slide (Thomson and Tiedmann, 1982)

- the eastern house was built 3-5 m from the crest, almost following the setback criteria

- the centre house was built below the crest

- the western most house was built up to the crest

- the houses were removed and the slope was flattened to 11°

SETBACK DETAILS

Active Slope

Name of landslide: 99 St. Slide, Peace River Town   Event no.: 75

Street address: 11417 99 St., 11421 99 St.

Slope type: overburden

Groundwater evidence:

Geology:

- till exposed, likely overlying sands and gravels (Barlow et al., 1990)
- fill evident in places

Structures damaged: 2 houses

Date structure was built: 1978

Date structure was damaged: 1989

SETBACK DETAILS

Abandoned Slopes

At landslide: 99 St. Slide, Peace River Town   Event no.: 75

Profile 1

Location: distance from slide - 140 m
direction from slide - north, same side of Peace R., 101 St. - 99 St.

Characteristics: pre-development slope angle (Barlow et al., 1990)

Groundwater evidence:

Slope angle: 22° (Barlow et al., 1990)

Profile 2

Location: distance from slide - 440 m
direction from slide - north, same side of Peace R., 101 St. - 99 St.

Characteristics: a slope with a mature tree cover

Groundwater evidence:

Slope angle: 24° (field measurement)

Profile 3

Location: distance from slide - 180 m
direction from slide - south, same side of Peace R., 99 St. - river

Characteristics: a slope with a resistant sandstone base

Groundwater evidence:

Slope angle: 26° (field measurement)

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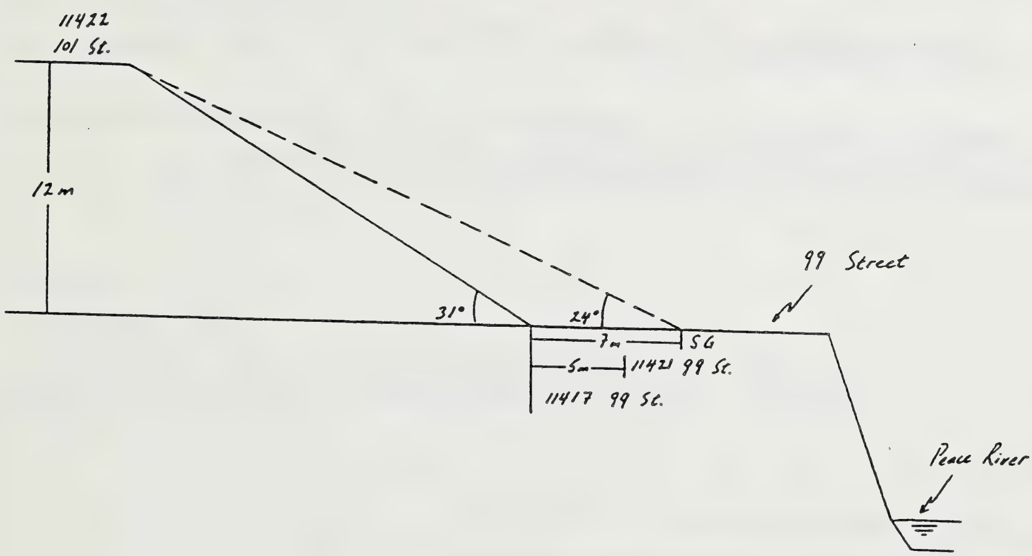
99 St. Slide, Peace River Town



Hs - slope height = 12 m (orthophoto measurement)

ßu - ultimate angle of stability = 24°

α - inclination of oversteepened slope

= 31° (orthophoto measurement)

R - potential long term regression

= Hs/tanßu - Hs/tanα = 7 m

En - net lateral river erosion = not applicable

SG - setback guideline

= R + En = 7 m

References:

1. Rod Burr, Surface Water, Alberta Environment, Peace River Town.

2. Surveys and Mapping Branch, 1977. Peace River (1974) 231-16 in part. Alberta Transportation, Edmonton.

3. Barlow, P., McRoberts, E., and Tenove, R., 1990. Stabilization of urban landslides in Peace River, Alberta. 43rd Canadian Geotechnical Conference. Canadian Geotechnical Society, Toronto.

4.

5.

Comments:

- slope behind the houses was cut (and filled)

- the City has bought one house which has lost its backyard

- the houses along 99 St. built at the base of the slope have virtually no backyards - houses 11417 99 St. and 11421 99 St. have been built no more than 5 m from the toe of the slope

- these houses therefore fall within the recommended "setforward" of 7 m

- it is possible that without remedial work, the other houses along this section of 99 St. may be affected by movement of the slope behind them.

SETBACK DETAILS

Active Slope

Name of landslide: Athabasca Elementary School Slide Event no.: 52

Street address: school along Muskeg Ck., houses on W. side of Davis St.

Slope type: bedrock

Groundwater evidence: many visible springs and surface ponding

Geology:

- clay shale bedrock
- overlain by a thin drift layer of colluvium derived from glacial, glaciofluvial, and glaciolacustrine deposits (Richard, 1987)

Structures damaged: N.W.corner of school (section demolished), 6 houses affected (1 abandoned)

Date structure was built: school - 1966 (1964-1968), 4 houses - 1965 (1964-1968), 2 houses - 1969 (1968-1969)

Date structure was damaged: 1968

SETBACK DETAILS

Abandoned Slopes

At landslide: Athabasca Elementary School Slide   Event no.: 52

Profile 1

Location: distance from slide - adjacent
direction from slide - south

Characteristics: not eroded by the creek

Groundwater evidence:

Slope angle: 6.5° (Hardy, R.M. and Associates, 1969)

Profile 2

Location: distance from slide - 600 m
direction from slide - northwest, opposite side of the creek

Characteristics: above a terrace

Groundwater evidence:

Slope angle: 8° (Topographic Services Ltd.)

Profile 3

Location: distance from slide - 840 m
direction from slide - southwest, opposite side of the creek

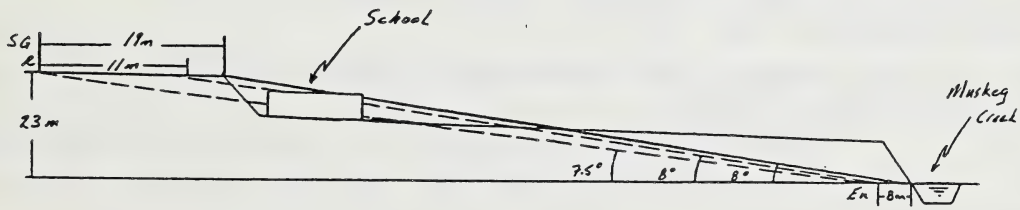
Characteristics: wall of Muskeg Creek Valley - mature trees

Groundwater evidence:

Slope angle: 8° (Suvan and Associates, 1989)

Determination of potential long term regression and setback guidelines.

Athabasca Elementary School Slide



Hs - slope height = 23 m (Hardy R.M. and Associates, 1970)

ßu - ultimate angle of stability = 7.5°

α - inclination of oversteepened slope

= 8° (Hardy, R.M. and Associates, 1970)

R - potential long term regression

= Hs/tanßu - Hs/tanα = 11 m

En - net lateral river erosion = 8 m

SG - setback guideline

= R + En = 19 m

References:

1. Topographic Services Ltd. Athabasca maps no. 8, 11, 12, 20. Edmonton, Alberta.

2. Hardy, R.M. and Associates Ltd., 1970. Athabasca Elementary School and vicinity proposed comprehensive area stabilization. Hardy and Associates Report no. E-1843. Edmonton. 15 p.

3. Richard, S.H., 1987. Surficial geology, Cross Lake, Alberta. Map no. 9-1986. Geological Survey of Canada, Ottawa.

4. Hardy, R.M. and Associates Ltd., 1969. Landslide Investigation Athabasca Elementary School, Athabasca, Alberta. Hardy and Associates Report no. 1843. Edmonton.

5. Suvan and Associates, 1989. Athabasca University. Hardy BBT file no. EG-06814-1. Edmonton.

Comments:

- Northwest Survey Corporation prepared contour maps of the entire slide area from recent aerial photographs

- flexible hoses are being used for gas services for the 5 houses on the west side of Davis St.

- previous report by Hardy and Associates - E-1843, Aug.14, 1970

- "creek is now eroding material at the outside bends of meander loops at only a slow rate but sufficient to continue to cause movement of the landslide" (Hardy and Associates, 1970)

- the prime causitive factors are erosion of the bank and high piezometric pressures

- remedial work consists of straightening and realigning the creek to avoid further erosion, installing horizontal drains, and diverting the surface water

SETBACK DETAILS

Active Slope

Name of landslide: Grierson Hill Slide, Edmonton Event no.: 12

Street address: Jasper Ave. / Grierson Rd.

Slope type: bedrock-based

Groundwater evidence: In the 1950s a significant amount of water was pumped from the mine.

Geology:

- clay overlies a clay till layer which overlies the bedrock
- the Cretaceous bedrock of the Edmonton Fm. is a clay shale with lesser amounts of sandstone and siltstone (Martin et al., 1984)
- coal and bentonite seams are in the bedrock below the mine

Structures damaged: total damage by 1915 - 2 stables and 14 houses

Date structure was built: prior to earliest photographs (1924)

Date structure was damaged: 1901 (7), by 1907 (4), by 1915 (5)

SETBACK DETAILS

Abandoned Slopes

At landslide: Grierson Hill Slide, Edmonton Event no.: 12

Profile 1

Location: distance from slide - 1480 m
direction from slide - northeast of left flank

Characteristics: above terrace, mature trees present

Groundwater evidence:

Slope angle: 15° (Transportation Planning, Planning Dept., 1979)

Profile 2

Location: distance from slide - 710 m
direction from slide - northeast of left flank

Characteristics: above terrace, mature trees present

Groundwater evidence:

Slope angle: 17.5° (Transportation Planning, Planning Dept., 1979)

Profile 3

Location: distance from slide -
direction from slide - south side of river (opposite slide)

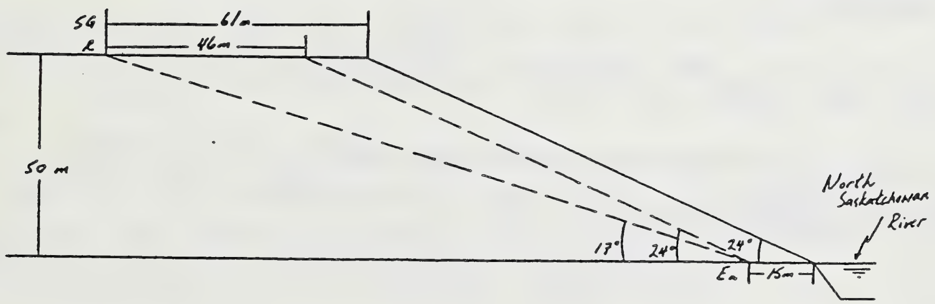
Characteristics: above terrace (Gallagher Park), mature trees present

Groundwater evidence:

Slope angle: 19° (Transportation Systems Design Dept., 1980)

Determination of potential long term regression and setback guidelines.

Grierson Hill Slide, Edmonton



Hs - slope height = 50 m (Poppitt, 1963)

ßu - ultimate angle of stability = 17°

α - inclination of oversteepened slope

= 24° (Martin et al., 1984)

R - potential long term regression

= Hs/tanßu - Hs/tanα = 46 m

En - net lateral river erosion = 15 m

SG - setback guideline

= R + En = 61 m

References:

1. Martin, R.L., Williams, E.R., Balanko, L.A., 1984. The Grierson Hill Slide, Edmonton, Alberta. 37th Canadian Geotechnical Conference. Canadian Geotechnical Society, Toronto. pp.125-133.

2. Poppitt, J.B., 1963. Grierson Hill Stabilization Project, Historical Summary. Report to the City of Edmonton, Edmonton City Archives. 11 p.

3. The Edmonton Bulletin, July 22, 29, and September 20, 23, 27, 30, 1901. Edmonton.

4. Pennell, D.G., 1969. Residual strength analysis of five landslides. Ph.D. Thesis, University of Alberta, Edmonton. 166 p.

5. Transportation Planning, Planning Dept., 1979. Edmonton 934+36. The City of Edmonton.
Transportaion Systems Design Dept., 1980. Edmonton 931+36. The City of Edmonton.

Comments:

- the initial landslide occurred in 1901, but since that time the scarp has retrogressed in response to continual erosion of the toe of the slide

- the total crest retreat between 1900 - 1958 was 43 m (Pennell, 1969), comparable to the potential long term regression of 46 m

- from 1911 to 1915, the lower portion of the slope was used as a dump, accumulating up to 15 m of garbage, straw, bricks, clay, and fill etc. (Pennell, 1969)

- river erosion has been extreme in the area - between 1887 and 1893 the river encroached into the bank about 15 m (Pennell, 1969)

- the outward movement of the slide and the placement of fill at the toe of the slope has pushed the toe out a maximum of 122 m from its 1893 position (Pennell, 1969)

Appendix B: continued

SETBACK DETAILS

Active Slope

Name of landslide: Lesueur Slide, North SasK. R., Edmonton   Event no.: 8

Street address:

Slope type: bedrock-based

Groundwater evidence: post slide perched water table - may indicate high pre-slide water level (Woods, 1973)

Geology:

- lake sediments overlie till which overlie Saskatchewan sands and gravels (above the bedrock)

- the bedrock, the Edmonton Fm., consists of a clay shale layer, followed by a bentonitic clay shale layer with a bentonite and coal seam, followed by bentonitic sandstone (Thomson, 1971)

Structures damaged: 1 house

Date structure was built: before the earliest photos (1949), added to in 1950's

Date structure was damaged: 1963

Abandoned Slopes

At landslide: Lesueur Slide, North Sask. R., Edmonton Event no.: 8

Profile 1

Location: distance from slide - 110 m
direction from slide - south of slide (adjacent to failed slope)

Characteristics: above terrace

Groundwater evidence:

Slope angle: 16° (Edmonton orthophoto 940+48)

Profile 2

Location: distance from slide - 700 m
direction from slide - south of slide

Characteristics: above terrace

Groundwater evidence:

Slope angle: 14.5° (Edmonton orthophoto 940+48)

Profile 3

Location: distance from slide - 1000 m
direction from slide - south of slide

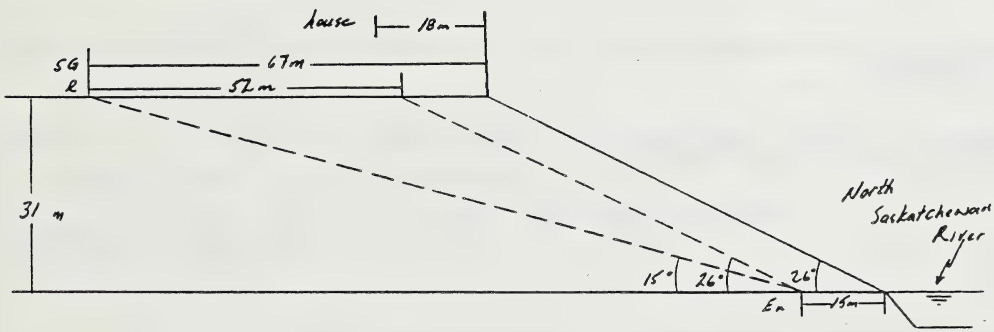
Characteristics: above terrace, and mature trees present

Groundwater evidence:

Slope angle: 15.5° (Edmonton orthophoto 940+48)

Determination of potential long term regression and setback guidelines.

Lesueur Slide, North Sask. R., Edmonton



Hs - slope height = 31 m (Thomson, 1971)

ßu - ultimate angle of stability = 15°

α - inclination of oversteepened slope

= 26° (Thomson, 1971)

R - potential long term regression

= $Hs/\tan\beta u - Hs/\tan\alpha$ = 52 m

En - net lateral river erosion = 15 m

SG - setback guideline

= R + En = 67 m

References:

1. Thomson, S., 1971a. The Lesueur Landslide, A failure in Upper Cretaceous claly shale. Proceedings, Ninth Annual Engineering Geology and Soils and Engineering Symposium, Boise, ID. pp. 257-287.

2. Woods, P.J., 1973. A re-analysis of the Lesueur Landslide. M.Eng. report. University of Alberta. 13 p.

3. Pennell, D.G., 1969. Residual strength analysis of five landslides. Ph.D. thesis. University of Alberta, Edmonton. 166 p.

4. Transportation Management Dept., 1983. Edmonton 940+48. The City of Edmonton.

5. Thomson, S., 1971b. Analysis of a failed slope. Canadian Geotechnical Journal. 8(4): 596-599.

Comments:

- the Lesueur house was built about 18 m from the crest, well within the recommended setback limit of 67 m

- the initial slope failure caused the crest to retreat about 11.6 m and by 1987 the scarp had retreated another 11.4 m (Thomson pers.comm)

- in the 24 years since the slide occurred, the crest of the slope retreated a total of about 23 m, suggesting that 67 m is a reasonable setback estimate

SETBACK DETAILS

Active Slope

Name of landslide: Mission Heights Slide, Grande Prairie Event no.: 97

Street address: 10101 81 Ave., 10105 81 Ave., (10109 81 Ave.)

Slope type: overburden

Groundwater evidence:

Geology:

- lacustrine (clay, silt, sand) exposed

- bedrock geology - Wapiti Formation: non-marine sandstone, shale, coal seams (Jones, 1966)

Structures damaged: 2 houses threatened and possibly a third

Date structure was built: 10105 81 Ave. (1982-1985), 10101 81 Ave, 10109 81 Ave. (1985-1987)

Date structure was damaged: June 1990

SETBACK DETAILS

Abandoned Slopes

At landslide: Mission Heights, Grande Prairie   Event no.: 97

Profile 1

Location: distance from slide - 160 m
direction from slide - south, same side of the valley

Characteristics: above abandoned meander

Groundwater evidence:

Slope angle: 13° (Grande Prairie orthophoto 114+80)

Profile 2

Location: distance from slide - 480 m
direction from slide - north, same side of the valley

Characteristics: above abandoned meander

Groundwater evidence:

Slope angle: 13° (Grande Prairie orthophoto 114+80)

Profile 3

Location: distance from slide - 140 m
direction from slide - north, opposite side of the valley

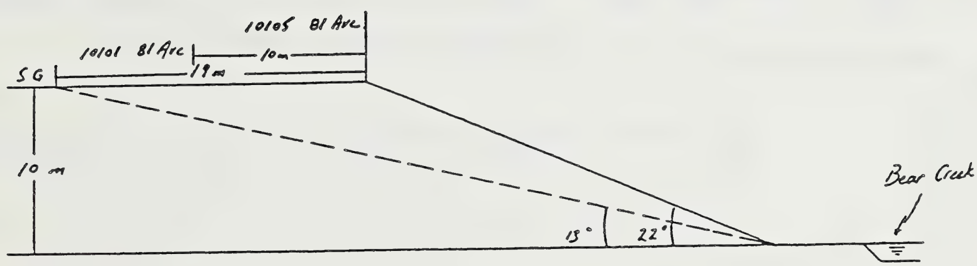
Characteristics: above abandoned meander

Groundwater evidence:

Slope angle: 11° (Grande Prairie orthophoto 114+80)

Determination of potential long term regression and setback guidelines.

Mission Heights, Grande Prairie



Hs - slope height = 10 m (orthophoto measurement)

ßu - ultimate angle of stability = 13°

α - inclination of oversteepened slope

= 22° (orthophoto and field measurement)

R - potential long term regression

= Hs/tanßu - Hs/tanα = 19 m

En - net lateral river erosion = not applicable

SG - setback guideline

= R + En = 19 m

References and Comments

References:

1. Bernd Manz, City Engineer, City of Grande Prairie.

2. Lisaway, homeowner (10105 81 Ave.)

3. Jones, J.F., 1966. Bedrock Geology of the Peace River District, Alberta. Map 27. Research Council of Alberta, Bulletin no. 16.

4. Alberta Bureau of Surveying and Mapping, 1983. Grande Prairie 114+80.

5.

Comments:

- 6 abandoned slope angles were measured - 4 were 13°, 1 was 11°, and 1 was 17°

- it is possible that the 11° slope has been abandoned for the longest period, and that the 17° slope is the most recently abandoned

- all the structures (including the third) were built within the setback guideline - 10101 81 Ave. was built approximately 10 m back from the crest, and 10105 81 Ave. was built up to the crest

- this suggests that remedial work is necessary to stabilize the slope

SETBACK DETAILS

Active Slope

Name of landslide: Park Hill Slide, Calgary Event no.: 4

Street address: corner of 1A Street and 38A Avenue, S.W.

Slope type: overburden

Groundwater evidence: - 1 m below the surface of slide mass - after drains 5 m

Geology:

- lacustrine clayey silt with lenses and layers of sand (Hardy et al., 1980)

Structures damaged: road relocated and house removed

Date structure was built: late 1940's and the 1950's

Date structure was damaged: 1967

SETBACK DETAILS

Abandoned Slopes

At landslide: Park Hill Slide, Calgary		Event no.: 4

Profile 1

Location: distance from slide - 1,300 m
direction from slide - northwest

Characteristics: opposite side of Elbow River, above terrace, park at base

Groundwater evidence:

Slope angle: 18° (field measurement)

Profile 2

Location: distance from slide - 1,350 m
direction from slide - northwest

Characteristics: opposite side of Elbow River, above terrace, park at base

Groundwater evidence:

Slope angle: 18° (field measurement)

Profile 3

Location: distance from slide - 180 m
direction from slide - south

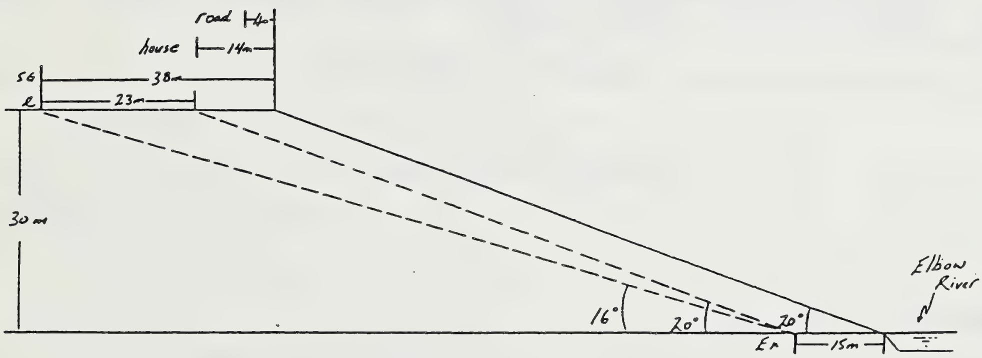
Characteristics: same side of Elbow River, above terrace, park at base

Groundwater evidence:

Slope angle: 13° (City of Calgary, 1975)

Determination of potential long term regression and setback guidelines.

Park Hill Slide, Calgary



Hs - slope height = 30 m (Hardy et al., 1980)

βu - ultimate angle of stability = 16°

α - inclination of oversteepened slope

= 20° (Hardy et al., 1980)

R - potential long term regression

= $Hs/\tan\beta u - Hs/\tan\alpha$ = 23 m

En - net lateral river erosion = 15 m

SG - setback guideline

= R + En = 38 m

References and Comments

References:

1. G.C. Johnston, P.Eng., City of Calgary.

2. Hardy, R.M., Clark, J.I., Stepanek, M., 1980. A summary of case histories spanning thirty years of slope stabilization in Calgary, Alberta. In: Slope Stability Problems in Urban Areas. Canadian Geotechnical Society, Toronto. 24 p.

3. Hardy, R.M. and Associates, 1970. Hillside Instability 38 Avenue and 1A Street S.W. Calgary, Alberta. Hardy, R.M. and Associates Ltd., Job No. CS 1836, Calgary.

4. Jack Clark, Memorial University, Newfoundland.

5.

Comments:

- the road was 4 m from the crest and the house was 14 m from the crest (Hardy et al., 1980)

- therefore, both the road and the house were well within the 38 m setback guideline

- the high groundwater level is possibly due to leaky services

SETBACK DETAILS

Active Slope

Name of landslide: Power Plant Slide, Medicine Hat　　Event no.: 25

Street address: along the South Saskatchewan River in W. Medicine Hat

Slope type: bedrock

Groundwater evidence: seepage from coal seam at till/bedrock contact

Geology:

- 1.5 m of gravel overlies a silty clay till layer
- at about 24 m is a 20 cm coal seam at the till/bedrock contact
- the bedrock is a clay shale

Structures damaged: Calgary Power utility pole (relocated)

Date structure was built: prior to earliest photographs (1949)

Date structure was damaged: moved in 1980

SETBACK DETAILS

Abandoned Slopes

At landslide: Power Plant Slide, Medicine Hat   Event no.: 25

Profile 1

Location: distance from slide - 3300 m
direction from slide - downstream, opposite side of the river

Characteristics: above a terrace, mature trees present

Groundwater evidence:

Slope angle: 14° (Redcliff/Medicine Hat orthophoto 544+20)

Profile 2

Location: distance from slide - 3300 m
direction from slide - upstream from slide, same side of river

Characteristics: above a terrace

Groundwater evidence:

Slope angle: 12° (Redcliff/Medicine Hat orthophoto 544+20)

Profile 3

Location: distance from slide - slope adjacent to the right flank
direction from slide - immediately east of slide

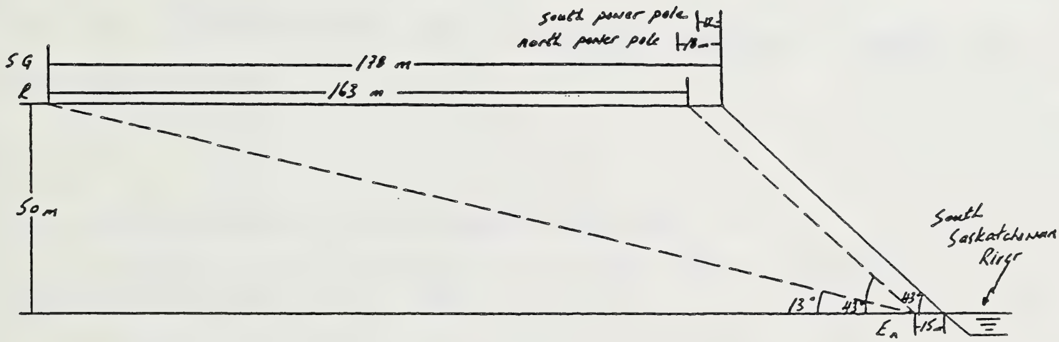
Characteristics: above a terrace

Groundwater evidence:

Slope angle: 13° (Redcliff/Medicine Hat orthophoto 544+20)

Determination of potential long term regression and setback guidelines.

Power Plant Slide, Medicine Hat



Hs - slope height = 50 m (MacKay and Thomson, 1980)

ßu - ultimate angle of stability = 13°

α - inclination of oversteepened slope

= 43° (MacKay and Thomson, 1980)

R - potential long term regression

= $Hs/\tan\beta u - Hs/\tan\alpha$ = 163 m

En - net lateral river erosion = 15 m

SG - setback guideline

= R + En = 178 m

References:

1. MacKay, C. and Thomson, S., 1980. A report on slope instability along the South Saskatchewan River and tributaries in the vicinity of Medicine Hat, Alberta. Alberta Environment.

2. Alberta Bureau of Surveying and Mapping, 1984. Redcliff/Medicine Hat 544+20.

3. Alberta Bureau of Surveying and Mapping, 1984. Medicine Hat 544+24.

4.

5.

Comments:

- MacKay and Thomson (1980) concluded that this landslide suggests that the valley walls may not be as stable as they appear to be, therefore, in the absence of a thorough engineering investigation, it would be prudent to have projects back from the valley crest a distance of 1.5 - 2 times the valley depth.

- the setback guideline of 178 m for this case history is high because the abandoned slopes in the area are at considerably lower angles than the oversteepened slope

- the 1962 air photos indicated that the low level terrace east of the slide area extended westward, protecting the toe of the slope below the power poles

- by 1980 the terrace had been completely eroded

- both power poles were set well within the setback guideline of 178 m; the south pole was 12 m back from the crest, and the north pole was 18 m back from the crest

SETBACK DETAILS

Active Slope

Name of landslide: Schoendorfer Slide, Manning Event no.: 96

Street address: sec. 27-91-23-5 (N. of Manning along the Notikewin River)

Slope type: overburden

Groundwater evidence:

Geology:

- the surficial deposits are glaciolacustrine (Fox, 1987)
- the Shaftesbury Fm. is the bedrock in the area, and is a marine shale and silty shale (Jones, 1966)

Structures damaged: garage threatened, house safe

Date structure was built: garage (Aug. 1976-July 1978), house (1976)

Date structure was damaged: (threatened) 1990

SETBACK DETAILS

Abandoned Slopes

At landslide: Schoendorfer Slide, Manning   Event no.: 96

Profile 1

Location: distance from slide - 70 m
direction from slide - west, same side of the Notikewin River

Characteristics: above an abandoned meander

Groundwater evidence:

Slope angle: 23°

Profile 2

Location: distance from slide - 200 m
direction from slide - west, same side of the Notikewin River

Characteristics: above an abandoned meander

Groundwater evidence:

Slope angle: 25.5°

Profile 3

Location: distance from slide - 330 m
direction from slide - west, same side of the Notikewin River

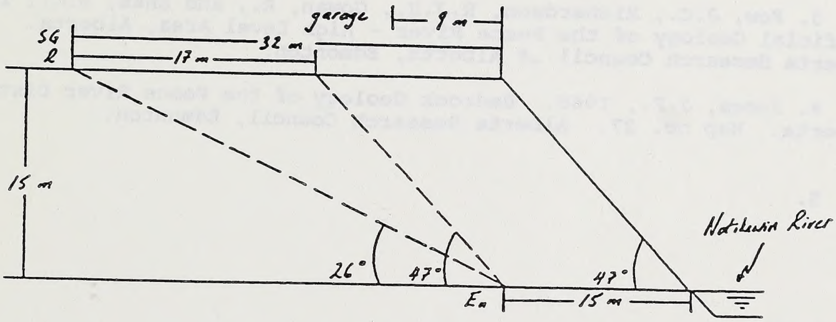
Characteristics: above an abandoned meander

Groundwater evidence:

Slope angle: 30°

Determination of potential long term regression and setback guidelines.

Schoendorfer Slide, Manning



Hs - slope height = 15 m (Surveys and Mapping Branch, 1976)

ßu - ultimate angle of stability = 26° (field measurement)

α - inclination of oversteepened slope

= 47° (field)

R - potential long term regression

= Hs/tanßu - Hs/tanα = 17 m

En - net lateral river erosion = 15 m

SG - setback guideline

= R + En = 32 m

References and Comments

References:

1. Greg Rycroft, Municipal Co-ordinator, Town of Manning.

2. Surveys and Mapping Branch, 1976. Manning. NTS series 84 C13. Dept. of Energy Mines and Resources, Ottawa.

3. Fow, J.C., Richardson, R.J.H., Gowan, R., and Sham, P.C., 1987. Surficial Geology of the Peace River - High Level Area, Alberta. Alberta Research Council of Alberta, Edmonton.

4. Jones, J.F., 1966. Bedrock Geology of the Peace River District, Alberta. Map no. 27. Alberta Research Council, Edmonton.

5.

Comments:

- the garage is located on an active slope of the Notikewin River while the house is located above a abandoned slope

- from the 1976 photographs it was evident that a relativel recent slide occurred below the location where the garage was to be built - the scarp was still well defined, and there was no vegetation

- as the garage was built approximately 9 m back from the crest, it falls within the setback guideline of 32 m

- it is likely that the garage will have to be moved